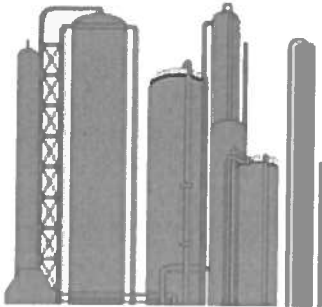


**REFINERY TRAINING
PROGRAM**



Human Factors

A Curriculum for Refinery Workers

Labor Occupational Health Program
Center for Occupational and Environmental Health
University of California, Berkeley

2001



This curriculum was developed and produced by:

Labor Occupational Health Program (LOHP)
Center for Occupational and Environmental Health
School of Public Health
University of California
2223 Fulton St., 4th Floor
Berkeley, CA 94720-5120

Phone: (510) 642-5507
E-mail: lohp@socrates.berkeley.edu
Web: www.lohp.org

Project Team: Gail Bateson, Pam Tau Lee, and Laura Stock.

Editing, Design, and Production: Gene Darling and Kate Oliver.

Graphics: Mary Ann Zapalac.

Our thanks to the following individuals who helped with the development of this curriculum:

Sabiha Gokcen, Ultramar Diamond Shamrock Corporation

Jo Haegert Greene, Contra Costa County Hazardous Materials Program
(formerly)

Jim Howe, United Auto Workers

Andrew S. Imada, Consultant

Nancy Lessin, Massachusetts AFL-CIO

Najmedin Meshkati, Dept. of Civil & Environmental Engineering, Dept. of
Industrial & Systems Engineering, University of Southern California

Paul Renner, Labor Institute

Suzanne Rodgers, Consultant

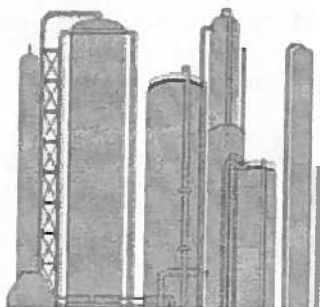
T.A. Seymour, PACE International Union (OSHEC)

Copyright © 2001, LOHP.

Cover photo copyright © 2001, Corbis. Used by permission.

Permission is granted to reproduce or adapt these materials for non-profit educational purposes, provided that copies are not offered for sale. Please credit LOHP and send a copy to the address above.

REFINERY TRAINING PROGRAM



Using the Curriculum

This curriculum was designed to give refinery workers a basic introduction to human factors and the role of human factors concepts in their company's safety plan. The training program provides an "awareness" level of understanding, and is appropriate for both operations and maintenance workers. It was developed by the Labor Occupational Health Program at U.C. Berkeley's School of Public Health, with funding from California's Contra Costa County.

Background

In December, 1998, following several major refinery accidents, Contra Costa County passed a new industrial safety ordinance (Industrial Safety Order 98-48). The ordinance requires refineries and some other large chemical plants in the county to develop new written safety plans that use a human factors approach. The goal is to help prevent major accidental releases of hazardous materials into the community. The new plans will also improve worker safety.

California refineries are already subject to two other important government safety regulations:

- Cal/OSHA'S Process Safety Management (PSM) standard
- Cal/EPA'S Risk Management Plan (RMP).

The new county ordinance calls for strengthening these existing regulations by putting greater emphasis on human factors. Each plant must now consider human factors in five areas of its operations:

1. Process Hazard Analysis
2. Root Cause Incident Investigation
3. Operating Procedures
4. Management of Change—Staffing Cuts
5. Employee Training.

For more detailed information about the ordinance, see Lesson One, Handout #1.

The ordinance recommends that all employees receive introductory “awareness” training about human factors and about their plant’s new safety plan.

This curriculum provides a model for delivering “awareness” training to workers in your plant. This type of training is only a first step in understanding human factors. Those workers who will participate on Incident Investigation Teams or Process Hazard Analysis Teams will need more specialized training.

The Curriculum

The curriculum consists of four lessons.

Lesson 1. Introduction to Human Factors

This lesson defines “human factors” and gives an overview of the new ordinance. It explains that human factors is a **new** approach to studying accidents and identifying safety hazards in the workplace. It introduces basic ideas and terms, emphasizing the importance of understanding the causes of “human error.”

Lesson 2. Finding Solutions

This lesson explains how human factors solves safety problems by designing processes, tools, and equipment to meet workers' needs. In small groups, participants practice using human factors methods to study typical workplace safety problems and devise solutions.

Lesson 3. Applying Human Factors to Refineries

The concept of "latent conditions" is introduced, and the importance of identifying latent conditions during safety inspections is stressed. Then, building on human factors concepts from previous lessons, participants meet in small groups to analyze actual refinery accidents. They use a checklist to find potential safety hazards in the scenarios presented.

Lesson 4. Your Company's Safety Plan

Each facility should develop its own Lesson Plan for Lesson Four. This may include a presentation by the company, explaining the specifics of its new safety plan and the role that human factors methods will play. To be consistent with the teaching style of the previous lessons, there should be opportunities for questions and class discussion. If possible, prepare a few visual aids (Overheads) about the company safety plan. You may also want to distribute the written safety plan and/or related materials as Handouts. Tabbed sections are provided in this binder to add your Lesson Plan and any Overheads and Handouts.

For Lessons 1–3, the curriculum supplies the following materials:

- A list of "Training Objectives," showing what participants will learn in each lesson.
- A chart called "Lesson at a Glance," showing all the presentations and activities that make up the lesson, along with the time and materials needed for each one.
- A "Detailed Lesson Plan," with a complete script for giving each presentation and leading each activity. Throughout each Lesson Plan are boxes called *Instructor's Notes*. These give quick directions for what to do at that point (show an Overhead, conduct a "brainstorm," etc.)

- A set of Overheads to show during class. Masters of the Overheads are provided in this binder.
- A set of Handouts to give to participants. Masters of the Handouts are provided in this binder. Some of these are for use during class, and others are reference materials for participants to keep and read later.

To present the curriculum, it is not necessary to be either an “expert” on human factors or a professional educator. The information and training instructions here should be sufficiently complete to allow any trainer to lead the workshop.

How To Present the Lessons

The total time needed for all four lessons is approximately four hours:

Lesson 1. 75 minutes.

Lesson 2. 60 minutes.

Lesson 3. 60 minutes.

Lesson 4. 45 minutes.

Depending on your own situation, the series may be presented several different ways:

Option A. Six-Hour Human Factors Workshop

You could present the entire set of lessons in six hours, including breaks and lunch.

Option B. Present Each Lesson Separately

You could present the lessons one at a time, covering them all over a period of days or weeks. If you use this option, it is important to present the lessons in sequence since they build on one another.

Option C. Present Lessons 1 & 2 Together, 3 & 4 Together

You could “pair up” the lessons and offer them in groups on two different dates.

Teaching Approach

The teaching approach used in this curriculum is highly interactive. It is based on the view held by many labor educators that people learn:

- 20% of what they hear
- 40% of what they read
- 60% of what they hear **and** read
- 80% of what they hear, read, **and** do.

This viewpoint, which emphasizes **participatory** training, serves as the foundation for this curriculum. Each lesson has questions for the class to discuss, and overhead transparencies that summarize the main points. Each lesson also includes small group exercises that encourage people to apply what they are learning. Adults learn best when they are actively involved in the process and can build on the life experiences they bring into the classroom. Accordingly, the trainer must take the role of a facilitator rather than a lecturer.

Teaching Methods

The following teaching methods are used in this curriculum:

1. Presentation by Trainer

Some material is presented by the trainer directly from the Lesson Plan. Although the Lesson Plan script gives a complete explanation of what to say, avoid simply reading the Lesson Plan to the class. Here are some tips:

- Read the entire Lesson Plan in advance and decide how you will present the material.
- Put everything in your own words. Remember that the Lesson Plan text is intended only as suggested language.
- If you want, use different examples or a different emphasis. Shorten sections you think are less important to your audience. Add extra material to sections that seem more important. The more relevant you can make the information, the more the class will learn.

- A sheet titled “In Your Own Words” is provided opposite each Overhead in the binder. Use it to make your own notes on the main points from the Lesson Plan and how you will present them.
- Use a chalkboard or flipchart often, even when the Lesson Plan doesn’t specifically tell you to. Make lists. Draw pictures and diagrams when possible.
- Encourage people to ask questions at any time. When someone in the group asks a question, first repeat it aloud to make sure everyone can hear it.
- Tell people there are no stupid questions. Don’t be afraid of questions you can’t answer. Assure people that you will find out and get back to them. Make a note of the question and who asked it. Then follow up. It’s failure to follow up that threatens your credibility, not lack of knowledge.
- Avoid lecturing or talking too much. No one likes to be lectured at!

2. “Questions and Answers” (Class Discussion)

Class discussion, using questions and answers, is a technique used frequently throughout the curriculum. The trainer asks a question to elicit answers from the class, and then the class discusses the answers. The Lesson Plan prompts the trainer when to treat material this way by showing the key word **ASK:**, followed by the question to pose to the class.

Various methods are then used to encourage participation, including “brainstorming” and using a flipchart to list answers given by participants. The Lesson Plan has full instructions.

After questions have been answered and discussed, the trainer may add background information and further explanation (if time permits).

Here are some tips for leading a successful discussion:

- Try to put the questions and answers in your own words. If you want, use different (or extra) questions.

- Pause for a few seconds after asking a question to give people a chance to respond.
- Answers are provided in the curriculum only as a guide for the discussion. Add extra information of your own if you want. Make the discussion relevant by drawing on examples from workers' own experience.
- Include everyone in the discussion. Address every question to the whole group. Encourage people to join in the discussion.

3. Small Group Exercises

Another technique used is the small group exercise. Each lesson has an exercise of this type. The class is divided into several groups, each of which works on a different (but related) problem. For example, small groups may work on Case Studies describing actual refinery accidents. After the groups meet, the entire class comes back together. Groups report on their work and share their answers with the whole class. This prompts a class discussion of the answers.

To conduct a small group exercise, follow the detailed instructions in the curriculum. Small groups should have no more than four to six people. Feel free to substitute your own exercises if you wish.

4. Overheads and Handouts

Overheads are used throughout the curriculum. Masters of the Overheads are provided in this binder (in a separate "Overheads" section following each Lesson Plan). Duplicate these onto transparencies for use with an overhead projector. Show each Overhead when the Lesson Plan tells you to do so. Also make paper copies of the Overheads to distribute to the class, since they have useful information that people may wish to keep.

Try to allow time for any questions from the class about each Overhead. Leave each Overhead on the screen until the Lesson Plan indicates the next one should be shown, since some Overheads help illustrate or explain material that follows in the Lesson Plan.

Handouts are various materials to copy and distribute to the class. Masters of the Handouts are provided in this binder (in a separate "Handouts" section following each Lesson Plan). They include Case Studies, Factsheets, Worksheets, and other items needed for class exercises.

Some Handouts give background information on subjects covered during the class, and are intended primarily to be read by participants afterward and kept as reference material.

5. Evaluation

Evaluation is an important part of the training process. Participant evaluations of the workshop will help you learn from mistakes and constantly improve as a trainer. Evaluation also makes possible continuous improvement of these training materials.

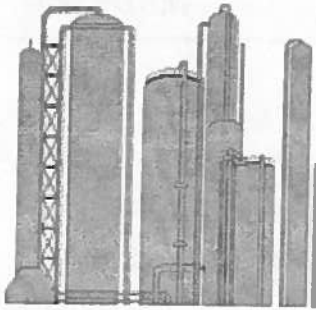
A brief Evaluation Form will be completed by participants after you have presented each lesson. A master of the form will be supplied with this binder. Make a copy for each participant. The results will give you an indication of what worked and what needs to be changed.

Preparing To Teach

As you prepare to present each lesson, complete the checklist below.

- Read in advance the entire Lesson Plan, Overheads, and Handouts.
- Think about how you will present the lesson. If you wish, write down important points from the Lesson Plan for easy reference while teaching. A blank page called "In Your Own Words" is provided for your notes opposite each Overhead in the binder.
- Duplicate and organize your Overhead transparencies. (Masters for duplication are in this binder.)
- Obtain an overhead projector, extra bulb, and screen.

- Obtain an extension cord and plug adapter for the projector if needed.
- Obtain a flipchart or easel, flipchart paper, markers, and masking tape. Or you can use a chalkboard, chalk, and eraser.
- Obtain any other materials shown in the “Materials Needed” section of the chart at the beginning of your Lesson Plan.
- Make a materials packet for each participant. For each packet, photocopy all Overheads, Handouts, and the Evaluation Form.
- Prepare an attendance list.
- Make a name tag or “tent card” for each person.



Introduction to Human Factors

Training Objectives

After completing Lesson One, students will be able to:

- Describe the new Contra Costa County industrial safety ordinance and its requirement that refineries use human factors methods.
- Explain how frontline operations and maintenance workers will be affected by the ordinance.
- List key elements of a human factors approach to safety, and explain how it differs from the traditional approach.
- Discuss why “worker error” is an inadequate explanation for accidents.
- Explain the difference between direct causes and underlying causes of an accident.

Lesson One at a Glance

Activity	Time	Materials
<p>1. Workshop overview.</p> <p>Instructor explains purpose and content of this training program, including an introduction to the new county safety ordinance.</p>	10 minutes	<ul style="list-style-type: none"> ■ Flipchart and markers. ■ Overheads #1–3. ■ Handout #1.
<p>2. Why do accidents happen?</p> <p>They may be blamed on worker error, but human factors looks for deeper causes.</p>	10 minutes	<ul style="list-style-type: none"> ■ Overheads #4–8.
<p>3. Human error.</p> <p>It isn't always "worker error." Anyone in the whole system can make an error.</p>	5 minutes	<ul style="list-style-type: none"> ■ Overheads #9–11. ■ Handout #2.
<p>4. Direct versus underlying causes.</p> <p>Key terms in the field of human factors.</p>	10 minutes	<ul style="list-style-type: none"> ■ Overheads #12–14.
<p>5. Small group exercise.</p> <p>Groups suggest possible causes of typical workplace incidents.</p>	15 minutes	<ul style="list-style-type: none"> ■ Overhead #15. ■ Handouts #3–6. ■ Flipchart paper and markers for groups.
<p>6. Report back and discussion.</p> <p>Groups report their answers to the class.</p>	20 minutes	
<p>7. Summing up.</p> <p>Reviewing ideas from Lesson One.</p>	5 minutes	<ul style="list-style-type: none"> ■ Overheads #16–18. ■ Handouts #7–8.

Total Class Time: 75 minutes

Detailed Lesson Plan

1. Workshop overview. (10 minutes)

Instructor's Note

- Show Overhead #1, *The New County Ordinance*.

Why Are We Here Today?

Let's begin by explaining why today's training is taking place. Here's some background.

- **County ordinance.** Most new workplace safety regulations come about due to major accidents. In December 1998, after several refinery accidents, Contra Costa County passed a new industrial safety ordinance (Industrial Safety Order 98-48).
- **New safety plans.** This law requires refineries, and some other industries in the county, to develop new safety plans. The plans will help prevent accidental releases of hazardous materials into the community, and also promote worker safety.
- **Human factors approach.** The new safety plans are different from those already required by other regulations. They must use a new approach called "human factors." We'll define this term later. For now, let's just say that human factors looks at safety differently from traditional methods. It's a new way of thinking for refineries, although it's been used before in other industries.
- **January 2001 deadline.** The human factors elements of each refinery's safety plan must be in place by Jan. 15, 2001.

Instructor's Note

- Show Overhead #2, *How Will the Ordinance Affect You?*

How Will the Ordinance Affect You?

What does the new ordinance have to do with you and your job? Here are some reasons that you may be affected.

- **Everyone will be involved in their employer's plan.** According to the ordinance, refineries' safety plans must include programs and activities that involve all employees—from top to bottom, from upper management to operations and maintenance workers.
- **Everyone will benefit.** Human factors has the potential to reduce accidents and make the workplace safer for everyone. Because it's a worker-centered approach, it can help make the workplace "user friendly." Applied correctly, it can result in work processes that are simpler and less confusing, and equipment that is easier and safer to use.
- **Human factors will become a standard way of looking at safety.** Your plant will be required to use the human factors approach. Everyone in the plant will need to understand it.
- **Everyone will be trained.** The ordinance recommends that all employees receive introductory "awareness" training about human factors and about their company's plan. You will get that introductory training at today's workshop. However, the workshop is only a first step in understanding human factors. You need more specialized training if you will have a direct role in your company's plan.
- **The union will help develop the plan.** The ordinance requires that each refinery work with the union when developing its plan. The union must also be involved in carrying out the plan. To participate in this process as a union rep or member, you must understand human factors principles and methods.
- **Your job duties may change.** You may be asked to serve on a team analyzing safety problems in your work area. The ordinance says that these teams must include frontline workers. It's also possible that new equipment or procedures may be introduced as a result of the new emphasis on human factors, and these may affect your job.

We won't go into all the specifics of the county ordinance. Handout #1 in your binder explains the ordinance in more detail. You may want to look it over later. It's more important to understand your own company's new safety plan, so we **will** take a closer look at your company's plan later.

Workshop Objectives and Agenda

Let's begin by going over the objectives of today's training. The workshop will answer these questions:

- What does human factors mean?
- What is a human factors approach to health and safety?
- What are the elements of your company's new safety plan?

A "human factors approach" is a new model for thinking about safety in the workplace. As with any new model, it may challenge some old ideas we have come to accept.

Instructor's Note

- Show Overhead #3, *Workshop Agenda*.

The workshop consists of four lessons:

1. Introduction to Human Factors
2. Finding Solutions
3. Applying Human Factors to Refineries
4. Your Company's Safety Plan.

The four lessons will be presented using an interactive style. There will not be long lectures. Instead, there will be a variety of activities in which you will participate, sometimes as a class, and sometimes in smaller groups. Feel free to ask questions at any time.

Let's begin Lesson One. In this lesson, we'll look at the key elements of a human factors approach to safety and see how it differs from the traditional approach. We'll also discuss "worker error" and why it is an inadequate explanation for accidents. Finally, we'll introduce some human factors terminology, including the difference between direct causes and underlying causes of an accident.

2. Why do accidents happen?

(10 minutes)

Instructor's Note

- Show Overhead #4, *The Human Factors Method*.

Human factors is a new, non-traditional way to improve workplace safety. Here's how human factors experts approach safety problems.

What. Human factors uses two techniques: it studies accidents to find their most basic causes, and it studies the workplace to find hazardous conditions that might cause the next accident.

Why. To remove hazards, improve safety, and prevent future accidents.

How. Human factors looks for solutions that change the workplace and make it safer. It tries to match equipment and work processes to human limits, capabilities, and needs. When the workplace is designed with human beings in mind, fewer accidents occur.

First we'll look at how human factors studies the causes of accidents. Later today, we'll see how it studies the workplace.

Instructor's Note

- Show Overhead #5, *What Do These Accidents Have in Common?*

The overhead shows three of the most significant industrial accidents in history:

Bhopal. In December, 1984, forty tons of methyl isocyanate, hydrogen cyanide, and other lethal gases were released into the air from Union Carbide's pesticide factory in Bhopal, India. Over 100,000 people near the plant got sick and several thousand died.

Chernobyl. In April, 1986, the reactor at the Chernobyl nuclear power plant in the Ukraine (former Soviet Union) overheated and had a core meltdown. Deadly radioactive material was released into the atmosphere. People nearby were exposed to radioactivity 100 times greater than the Hiroshima bomb. People, crops, and animals all over Northern Europe suffered damage.

Three Mile Island. In March, 1979, at the Three Mile Island nuclear power plant in Pennsylvania, a reactor core overheated. The reactor went out of control and the core came close to a complete meltdown.

Initial investigations of all three accidents identified the same basic cause.

ASK: “Can you guess what was found to be the common cause?”

All three of these accidents were initially blamed on **worker error**.

Instructor's Note

- Show Overhead #6, *Three Mile Island—Initial Accident Investigations*.

For example, this is what a federal commission initially said about Three Mile Island:

“The major cause of the accident was due to the inappropriate actions by those who were operating the plant.”

Instructor's Note

- Show Overhead #7, *Other Accidents in the News*.

It's very common for management, politicians, and the media to blame workers for accidents. Here are some recent headlines that show the usual way of thinking.

But later studies of Bhopal, Chernobyl, and Three Mile Island turned up a more complex picture. Experts looked deeper and found that the accidents were actually caused by a combination of several factors. “Worker error” was just a surface level cause.

Instructor's Note

- Show Overhead #8, *Looking Deeper*.

Here are some deeper causes that were found:

- All three accidents started on the graveyard shift—between one and four a.m. During these hours people are fatigued, less alert, and less able to respond to unusual circumstances.

- All three plants had serious deficiencies in their maintenance and inspection programs. There was a long backlog of maintenance requests and a lack of adequate maintenance staff.
- All three plants had inadequate worker training programs. When faced with unusual upset conditions, workers simply didn't know how to respond.

Obviously other factors were involved in these accidents besides those we have listed. The important point is that the "worker error" theory doesn't begin to explain the accidents. Today's accident investigators try to look deeper. Instead of automatically blaming workers, they want to understand **what** happened, and also **how** and **why** it happened. This is the heart of the human factors approach.

The old ways of investigating accidents no longer work. Our plants are getting more complex and automated. We need to use new ways that identify the underlying causes of accidents. Without knowing the real causes we can't prevent similar accidents in the future.

3. Human error.

(5 minutes)

Human factors places a lot of emphasis on human error, but it's not a question of blame. The purpose is to find the reasons errors are made.

The traditional safety approach focuses on modifying the behavior of workers. When an incident occurs, this approach looks at what the worker did or didn't do. Was the worker careful or careless? Did he or she follow procedures? Did he or she do the wrong things or do them in the wrong order? The traditional approach often blames the worker and sees the solution as simply getting people to work safer.

Human factors takes a different view. Instead of looking only at individual behavior to explain an incident, human factors looks at what made the error possible. It tries to identify and eliminate "error likely" situations by studying the whole operation.

The human factors approach is to reduce human error by changing the workplace, not the worker. Sometimes operator error is very likely or even inevitable, given the way the system is set up. You have to look at the whole system to find out why an error happened and find ways to eliminate future errors.

Also, human factors assumes that anyone in the whole system can make a “human error.” It’s not always just the worker. In other words, “human error” doesn’t always mean “worker error.”

Instructor’s Note

- Show Overhead #9, *Who Might Make an Error?*

ASK: “Who might be responsible for human error in a refinery?”

Instructor’s Note

- As people respond, list answers on a flipchart sheet. After a few minutes, show Overhead #10, *Human Error Happens at All Levels.*

Possible answers may include people responsible for:

- **Research and development.** R&D may not adequately study all the properties of new materials and processes, or may not report all their findings.
- **Design and engineering.** Plant designers and engineers may fail to consider the safety of the whole system and how its parts interact. Safety should always be “engineered in.”
- **Construction and installation.** Contractors may “cut corners” to save money, or may deviate from the original plans for some other reason. They may not adequately test their work.
- **Training.** The plant may not train operators how to deal with all possible situations.
- **Operations.** Operators and supervisors may not follow proper procedures.
- **Maintenance and inspection.** Maintenance may be inadequate, or the activities of maintenance personnel may disturb processes and equipment.
- **Plant management.** Managers may pressure workers to work too fast, work long hours, or work in unsafe ways. Or they may fail to issue and enforce clear procedures.
- **Corporate management.** Decisions on budget, equipment, and staffing may not be made with safety in mind.

So when we use the term “human error,” we are not necessarily saying “blame the worker.” For some more detailed examples, look at Handout #2 in your binder.

Instructor's Note

- Show Overhead #11, *Labor and Management Agree.*

Both labor and management agree that we should avoid an approach that blames the worker. According to the Chemical Manufacturers Association:

“The vast majority (80-85%) of human errors primarily result from the design of the work situation (the tasks, equipment, and environment) which managers directly control.”

One union human factors expert says:

“Blaming workers for safety failures is like blaming the snowflake for the avalanche.”

4. Direct versus underlying causes.

(10 minutes)

Instructor's Note

- Show Overhead #12, *Direct Causes.*

Now we'll look at some of the terminology that human factors uses.

Direct cause. The first question people usually ask after an accident is “What happened?” They are asking what immediate event or condition caused the accident. Human factors calls these direct causes.

Active human error and technical failure. Most direct causes of an accident can be divided into these two categories. An active human error is something a person did wrong, and a technical failure is something that went wrong with equipment.

The overhead shows some examples of direct causes—both active human errors and technical failures. Human factors focuses on active human errors, not technical failures.

Instructor's Note

- Show Overhead #13, *Human Factors Terms*.

Notice that this overhead has a picture of an iceberg. Human factors often thinks of accidents as like an iceberg. Only a small part of the iceberg is above water. That's the direct cause of the incident, the part that's obvious, the answer to the question "What happened?" Therefore, we put "direct cause"—along with "active human error" and "technical failure"—above the water line.

However, direct causes are just superficial causes. They aren't the real, deeper causes that human factors is interested in. On the iceberg, the deeper causes are below the water line. The underwater part is much larger, but invisible.

Here are two new terms that we've put **below** the water line:

Underlying cause and **root cause**. Human factors looks beyond direct causes to find underlying or root causes. These don't just answer the question "What happened?" They try to answer the questions "How and why did it happen?" These causes are often found in decisions made away from the shop floor—in what are called management and organizational factors.

An accident usually has many underlying causes. A root cause is an underlying cause that is one of the **primary** reasons the accident occurred.

ASK: "What are some examples of underlying or root causes of accidents?"

Instructor's Note

- As people respond, list answers on a flipchart sheet. After a few minutes, show Overhead #14, *Underlying and Root Causes—Some Examples*.

Possible answers include:

- Poor design of processes and equipment
- Lack of clear labeling
- Inadequate operating procedures

- Poor layout of indicators and controls
- Equipment that is in an unsafe location or difficult to access
- Lack of inspection and preventive maintenance
- Inadequate training for normal and emergency situations
- Fatigue due to long hours or late hours
- Inadequate staffing levels.

Human factors devotes a lot of attention to finding the underlying and root causes of accidents. If these causes are not identified and eliminated, it is more likely that a similar accident will occur in the future.

5. Small group exercise. (15 minutes)

Instructor's Note

- Show Overhead #15, *Looking for Causes*.

Next we'll do an exercise in small groups. Each group will consider one of the incidents shown on this overhead:

1. Someone opened the wrong valve.
2. Someone pushed the wrong button.
3. A pipe leaked.
4. Someone didn't respond properly to an alarm.

There are four worksheets (Handouts #3-6) in your binder. Each worksheet shows one of these incidents.

In your group, turn to the worksheet that you're assigned, think about the incident, and look at the picture carefully. Then your group should "brainstorm" about possible underlying causes of the incident.

Your group will be given a large flipchart sheet to use when you report back to the class. Choose someone in your group to record your list of possible underlying causes on this sheet as you work.

Also choose someone to present your answers to the class later. This person should be prepared to explain **why** you think each of your possible causes might have contributed to the incident.

Notice that your worksheet has the same iceberg we looked at earlier. We put the picture of the incident and its description (direct causes) above the water line. It will be your job to identify the deeper causes below the water line (underlying causes).

Try to get to the most basic causes of the incident. After you come up with a possible cause, keep asking "Why?" For example, if you think one cause of the incident might be that an operator was fatigued, this is probably just a surface level cause. You should ask yourself **why** he or she was fatigued.

You'll have about 15 minutes.

Instructor's Note

- Divide the class into groups of 5 or 6 people each.
- Assign **one** of the four worksheets (Handouts #3–6) to each group. (It's OK to assign the same worksheet to more than one group.)
- Give each group a blank flipchart sheet and a set of markers. Ask them to choose someone to record their list of possible underlying causes on this sheet.
- Also ask each group to choose someone to report their answers, and reasons for them, to the whole class later.
- Circulate among the groups as they work to make sure they are on track and to answer any questions.

6. Report back and discussion.

(20 minutes)

Instructor's Note

- Bring the class back together.
- Show Overhead #15, *Looking for Causes*, again and leave it on the screen while the groups report.
- Have all the groups post their completed flipchart sheets at the front of the class.
- In turn, ask each group's designated person to report on the possible causes they identified. Using the flipchart and the picture on the overhead, they should list each possible cause and explain **why** the group believes it might have contributed to the incident.
- Others in the group can add to the report if they wish. Allow time for the class to discuss the answers.
- For ideas, see the *Instructor's Discussion Guide* below.

Instructor's Discussion Guide

Listed here are possible underlying causes of each incident. Remember that groups may suggest causes which are not shown here, but which are equally valid.

1. Someone opened the wrong valve.

- Lack of clear and accurate labeling. (Which valve is which? Which direction is open and which is closed?)
- Poor design. (Why are valves all so similar, making them hard to distinguish? Why are there no interlocks to prevent opening the wrong valve?)
- Poor communication. (Did the worker get clear instructions and know what he was supposed to do?)
- Lack of training in how to do the job in normal and emergency situations.

- Fatigue due to long or late hours.
- Inadequate or unclear operating procedures.

2. Someone pushed the wrong button.

- Lack of clear and accurate labeling.
- Poor layout of buttons. (Are they too close together? Too similar in shape and appearance?)
- No lockout or “fail-safe” system. (Covers could be put on some buttons to reduce the chance of pushing the wrong one.)
- Poor communication.
- Lack of training in how to do the job in normal and emergency situations.
- Fatigue due to long or late hours.
- Inadequate or unclear operating procedures.

3. A pipe leaked.

- Lack of an overall system of preventive maintenance and inspection.
- Poor design of equipment.
- Pipe with wrong specs installed. (Couldn't handle pressure.)
- Poor training of maintenance personnel.
- Poor communication. (Could cause valves to be set incorrectly.)
- Understaffing. (Could cause delays in maintenance.)
- Production pressures. (Could cause delays in maintenance.)
- Tight budget. (Could cause delays in maintenance or lead to purchase of cheaper, inferior equipment.)

4. Someone didn't respond properly to an alarm.

- Poorly designed control panel and alarm system. (There are too many buttons and alarms. It's hard to distinguish the important ones. People can't process this much information.)
- Poor placement of indicators and controls. (Some are difficult to read or to access.)
- Distraction. (Operator is talking on phone.)
- Lack of training in how to do the job in normal and emergency situations.
- Fatigue due to long or late hours.
- Understaffing.
- Inadequate or unclear operating procedures.

7. Summing up.

(5 minutes)

Let's conclude Lesson One by taking a closer look at two important ideas we discussed—**active human errors** and **underlying causes**.

Instructor's Note

- Show Overhead #16, *Active Human Errors*.

Remember that active human errors are one kind of direct cause, so they go above the water line on the iceberg drawing. They're the direct causes that human factors is most interested in. Let's look at them in more detail. Active human errors:

- Are often cited as the actions that directly caused an accident.
- Are usually made by people on the front line—for example, a refinery operator, a maintenance worker, a pilot, an air traffic controller, a police officer, etc.
- Are just surface level causes. They don't explain how and why an accident happened.

Instructor's Note

- Show Overhead #17, *Underlying and Root Causes*.

Remember that underlying and root causes go below the water line on the iceberg. They are:

- The **primary** reasons for an accident or “near miss.”
- Hidden safety problems that played a role in an accident and might contribute to the next one as well.
- Conditions that make it harder for people to do their jobs, and make human error more likely.

Here's a quote from a human factors expert:

“Putting the immediate causes right will prevent only the last accident from happening again; attending to the underlying causes may prevent many similar accidents.”

Many incidents are repeated because previous fixes only addressed direct causes.

Think about the type of recommendations that come out of an investigation that focuses on underlying and root causes. They are quite different from traditional recommendations focusing on individual operators. If you look only at operator error, recommendations usually deal with changing behavior through motivational campaigns, punishment, or a combination of rewards and punishment. Effective prevention requires determining the root causes, and often changing management and organizational safety systems.

Here's an example of a recent human factors investigation. In 1989, a vapor cloud explosion at the Phillips petrochemical plant in Houston, Texas killed 23 people and injured 130. The accident occurred during routine maintenance when highly flammable gases were released through an open valve and ignited.

Instructor's Note

- Show Overhead #18, *OSHA Studies Phillips Explosion*.

OSHA, the U.S. government safety and health agency, used human factors methods to investigate the accident. OSHA identified many underlying causes, including inadequate lockout/tagout procedures, ignition sources that were too close to flammable chemicals, air hoses that were connected backwards, and control equipment that was not fireproof.

OSHA then issued this report, which triggered new regulations designed to prevent similar accidents. Although there were subsequent incidents at the Phillips plant in Houston, these regulations provide valuable guidance for improving workplace safety.

There are two handouts in your binder with more information on human factors studies of major accidents. You may want to look them over later. Handout #7 covers lessons learned from refinery accidents, and Handout #8 covers lessons from Three Mile Island.

Xerox ColorQube 9202 SMTP Transfer Report

XEROX

Job Status: FAILED

Job Information

Device Name: XRX0000AAD3851F
Submission Date: 02/29/16
Submission Time: 02:06 PM
Images Scanned: 38
Size: 0
Attachment Name: Scanned from a Xerox multifunction device.pdf
Format: Image-Only PDF

SMTP Server

Address: calmail.berkeley.edu:25

Message Settings:

Subject: Scanned from a Xerox multifunction device
From: DoNotReply@berkeley.edu
Reply To: DoNotReply@berkeley.edu
To:

1. keistrel@berkeley.edu

XEROX®

Lesson One

Overheads



In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

The New County Ordinance

Contra Costa County's Industrial Safety Order 98-48 says that refineries must develop new safety plans.

These plans:

- Will help prevent major accidental releases of hazardous materials into the community, and also promote worker safety.
- Must use a new approach called "human factors," which looks at safety differently from traditional methods.

Human factors elements of the plans must be in place by January 15, 2001.





In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

How Will the Ordinance Affect You?

- Everyone will be involved in their employer's safety plan—from upper management to operations and maintenance workers.
- Everyone will benefit—human factors can make the workplace safer and more “user friendly.”
- Human factors will become a standard way of looking at safety in your plant.
- Everyone will get “awareness” training about human factors and about their company's plan.
- The union will help develop the plan.
- Your job duties may change. Teams analyzing safety problems must include frontline workers. New equipment and/or procedures may be introduced.



In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Lesson One Overhead #3

Workshop Agenda

- Lesson 1** **Introduction to Human Factors**

- Lesson 2** **Finding Solutions**

- Lesson 3** **Applying Human Factors to Refineries**

- Lesson 4** **Your Company's Safety Plan**





In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

The Human Factors Method

WHAT

Study accidents
to find causes

Study the
workplace
to find hazardous
conditions



WHY

- To remove hazards
- To improve safety
- To prevent future accidents



HOW

Match equipment and
work processes to
human limits,
capabilities, and needs

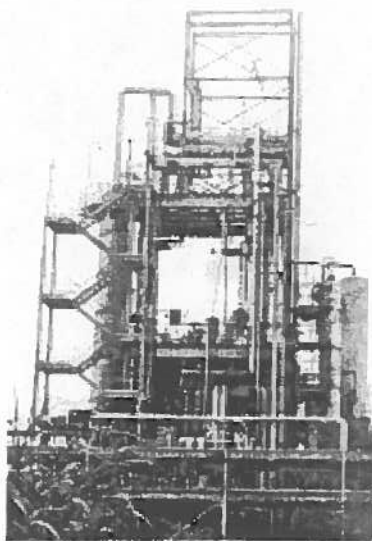


In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Lesson One Overhead #5

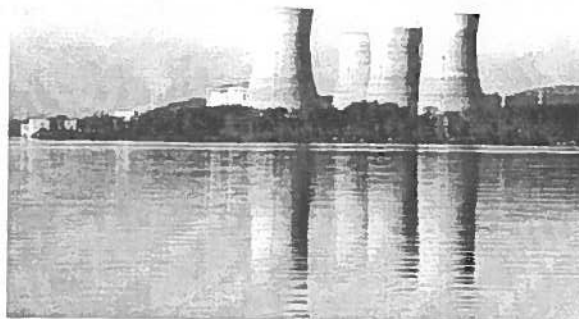
What Do These Accidents Have in Common?



Bhopal Chemical Plant,
1984 (India)



Chernobyl Nuclear Reactor,
1986 (Ukraine)



Three Mile Island Nuclear
Reactor, 1979 (USA)



In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Three Mile Island—Initial Accident Investigations

- A federal commission found that:

“The major cause of the accident was due to the inappropriate actions by those who were operating the plant.”

- Reports by Babcock and Wilcox (manufacturer of the reactor) and others reached the same conclusion.



In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Other Accidents in the News

San Francisco Chronicle

Unocal Says Error Caused Blaze

San Francisco Examiner

PG&E punishing workers for Dec. 8 blackout

The New York Times

Disaster in Bhopal: Where Does Blame Lie?



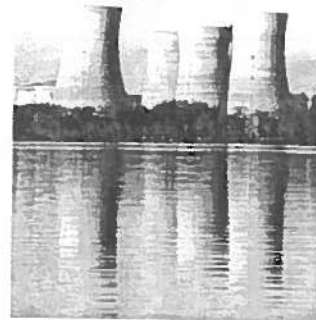
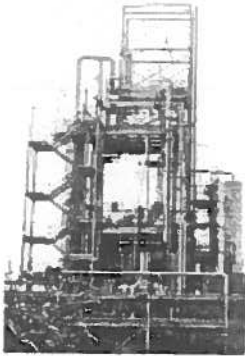
In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Looking Deeper

Later investigations of Bhopal, Chernobyl, and Three Mile Island found that these accidents weren't just the result of "worker error." All had deeper causes.

- **Started during graveyard.** All the accidents started between 1 a.m. and 4 a.m., when fatigue is a problem.
- **Lack of maintenance.** All the plants had poor maintenance and inspection programs, with serious delays in preventive maintenance
- **Poor worker training programs.** In all three plants, workers didn't know what to do during upset conditions.





In Your Own Words

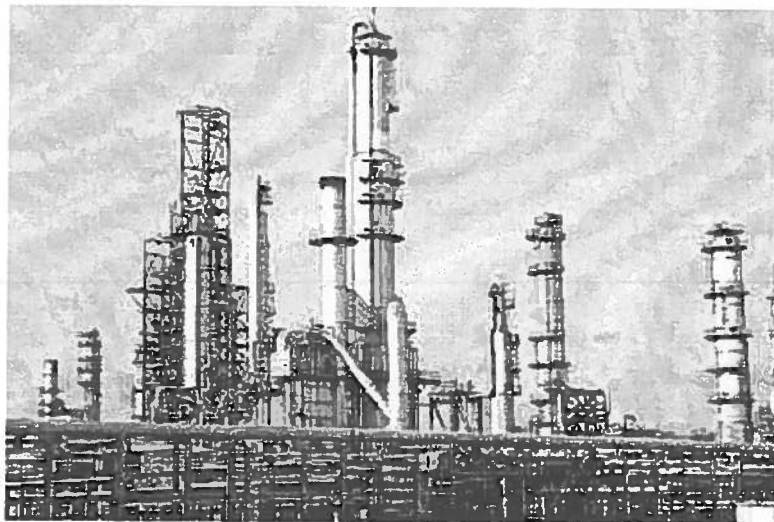
If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Lesson One Overhead #9

Who Might Make an Error?

Anyone in the whole system can make a human error.
It's not always just the worker.

Who else could be responsible for human error in a refinery?





In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Human Error Happens at All Levels

- Research and development
- Design and engineering
- Construction and installation
- Training
- Operations
- Maintenance and inspection
- Plant management
- Corporate management.



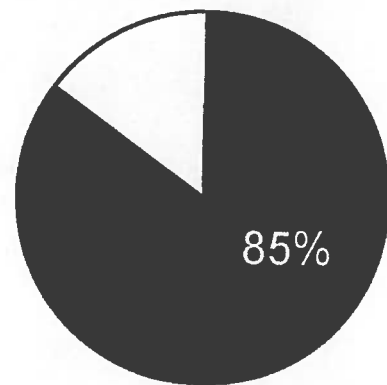
In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Labor and Management Agree

“The vast majority (80-85%) of human errors primarily result from the design of the work situation (the tasks, equipment, and environment) which managers directly control.”

—Chemical Manufacturers Association



“Blaming workers for safety failures is like blaming the snowflake for the avalanche.”

—Glenn Erwin, PACE

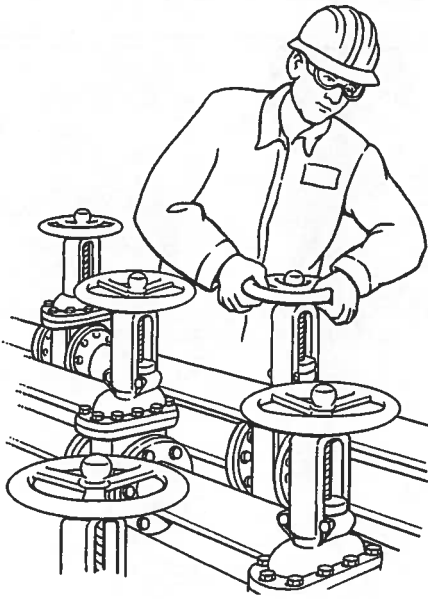




In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

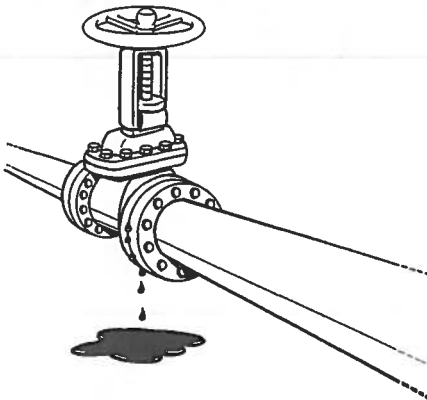
Direct Causes



Active human errors

- Someone opened the wrong valve.
- Someone pushed the wrong button.
- Someone failed to follow proper procedures.

Technical failures



- A pipe ruptured.
- A seal failed.
- An automatic valve failed to open or close.

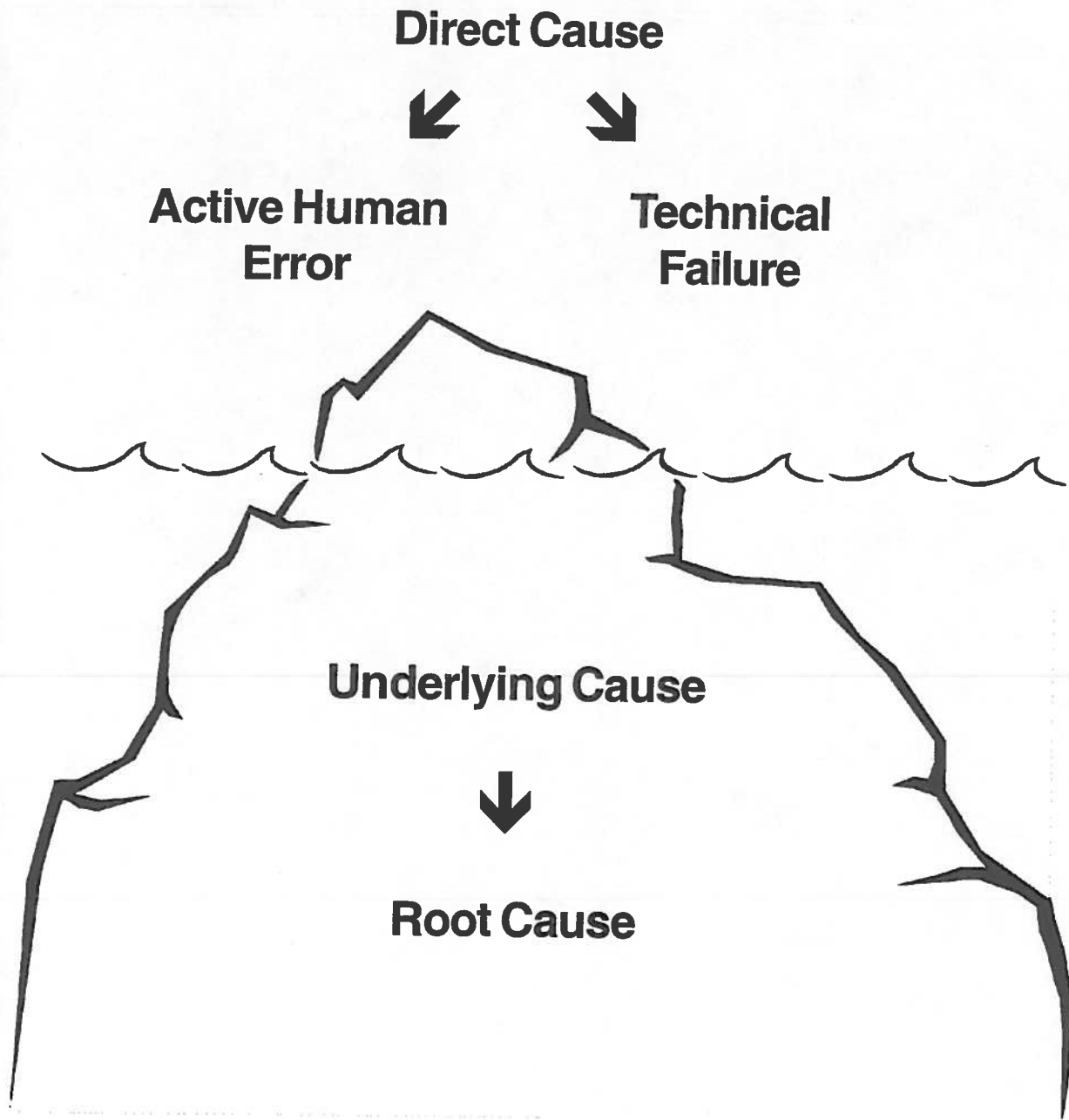
Human factors focuses on active human errors, not technical failures.



In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Human Factors Terms

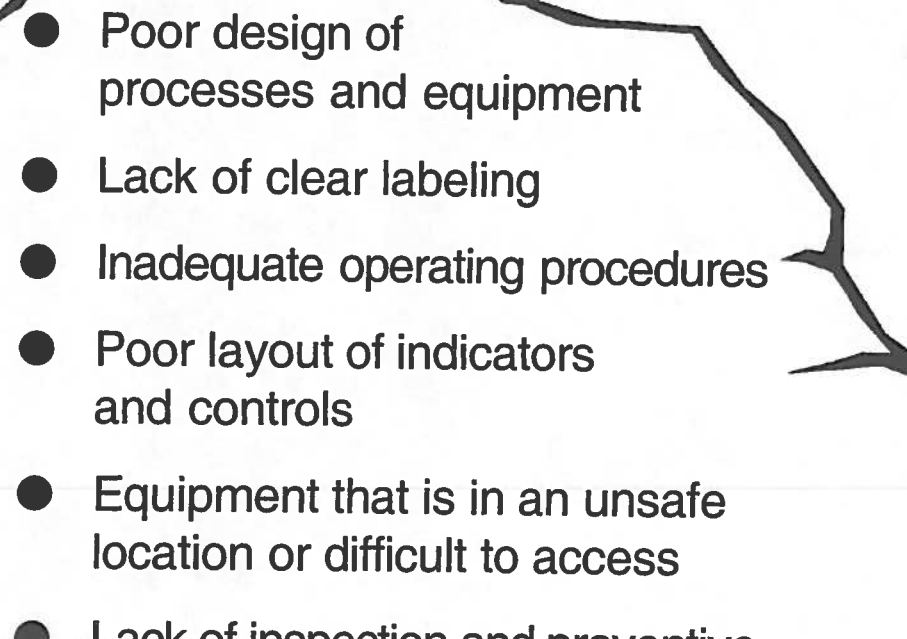




In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Underlying and Root Causes— Some Examples

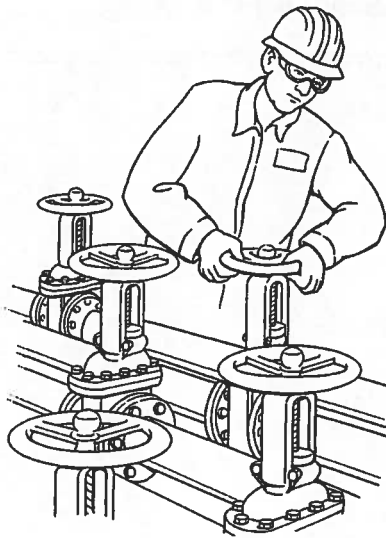
- 
- Poor design of processes and equipment
 - Lack of clear labeling
 - Inadequate operating procedures
 - Poor layout of indicators and controls
 - Equipment that is in an unsafe location or difficult to access
 - Lack of inspection and preventive maintenance
 - Inadequate training for normal and emergency situations
 - Fatigue due to long hours or late hours
 - Inadequate staffing levels.



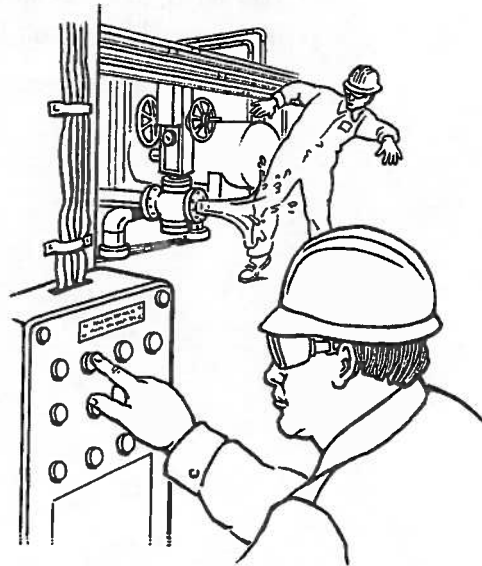
In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

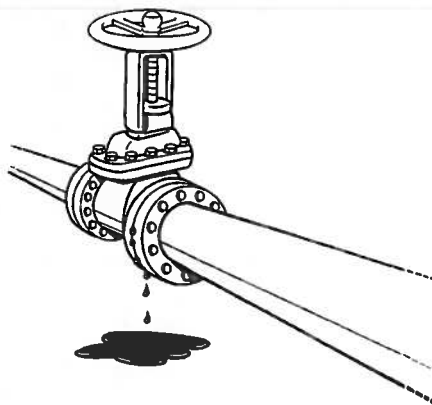
Looking for Causes



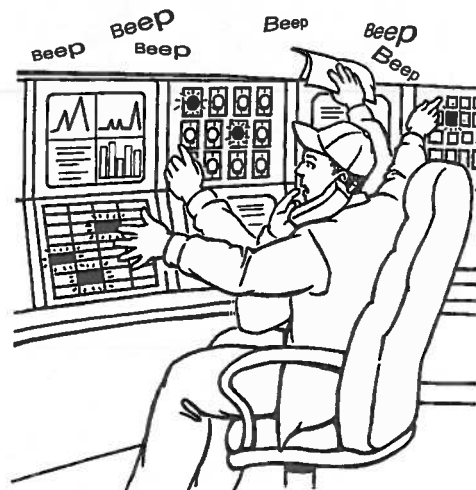
Someone opened the wrong valve



Someone pushed the wrong button



A pipe leaked



Someone didn't respond properly to an alarm

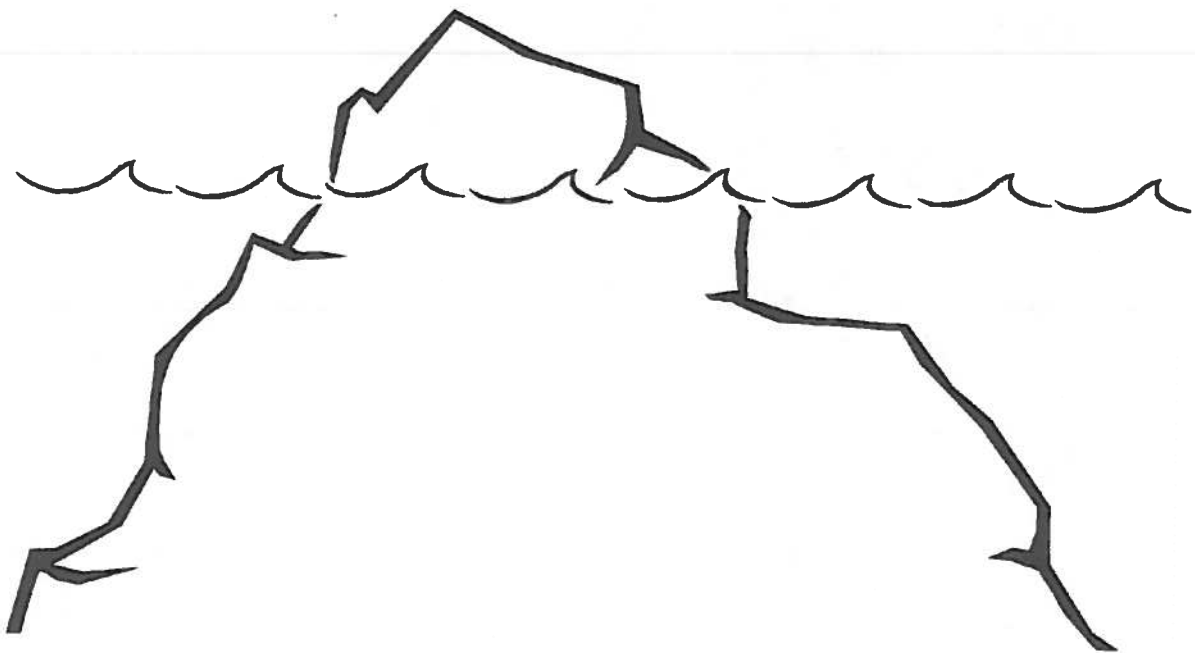


In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Active Human Errors

- Are often cited as the actions that directly caused an accident.
- Are usually made by people on the front line—refinery operators, maintenance workers, pilots, air traffic controllers, police officers, etc.
- Are surface level causes. They don't explain **how** and **why** an accident happened. The human factors method looks for deeper underlying causes.

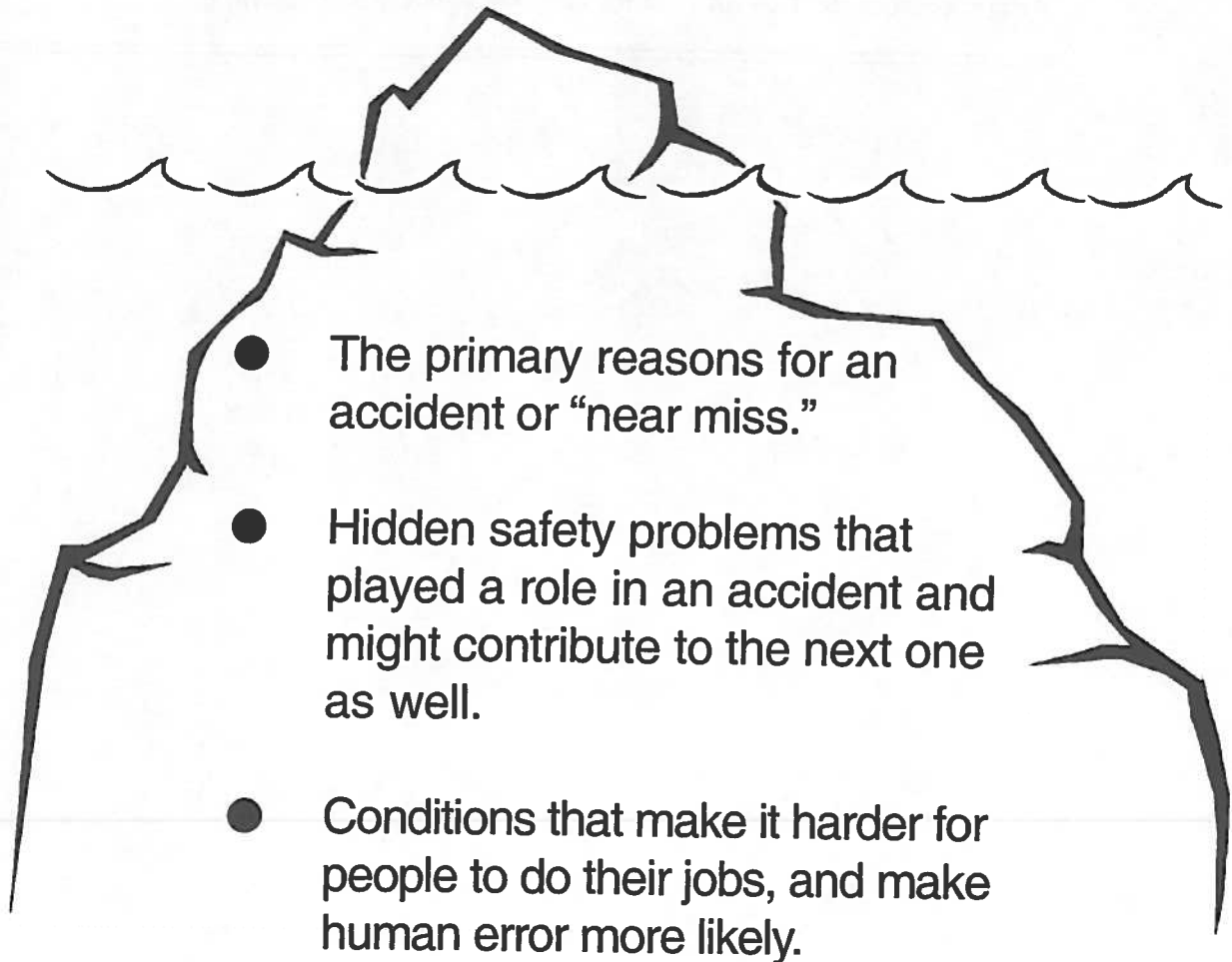




In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Underlying and Root Causes



“Putting the immediate causes right will prevent only the last accident from happening again; attending to the underlying causes may prevent many similar accidents.”

—Human Factors Expert



In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Lesson One Overhead #18

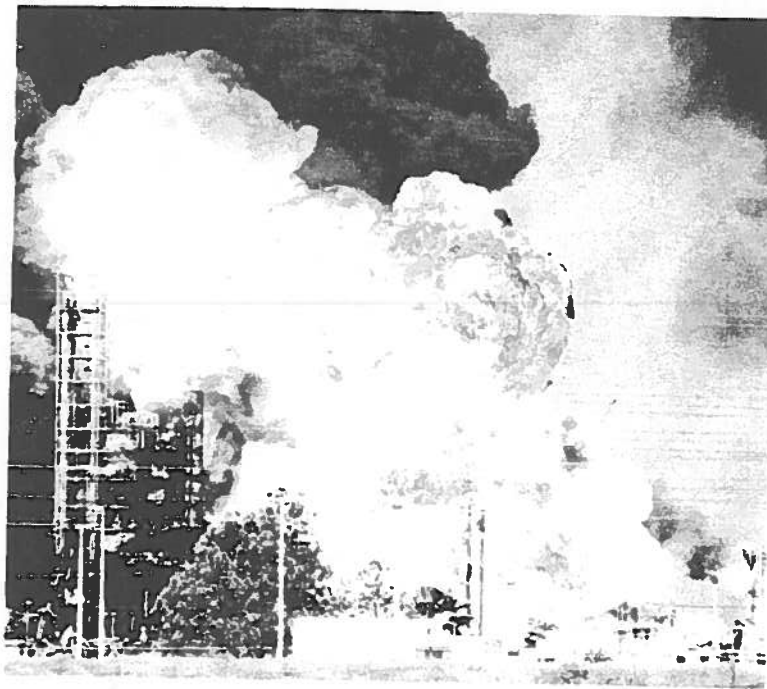
OSHA Studies Phillips Explosion

The Phillips 66 Company Houston Chemical Complex Explosion and Fire

A Report to the President

U. S. Department of Labor
Occupational Safety and Health Administration

April 1990



Lesson One Handouts



Contra Costa County's Human Factors Ordinance

Contra Costa County's new Industrial Safety Order 98-48 requires each refinery in the county to develop a new written safety plan. Other large chemical plants are also covered by the ordinance. The goal is to help prevent major accidental releases of hazardous materials into the community. The ordinance will also promote worker safety.

Refinery safety plans must use a new, non-traditional approach called human factors. Human factors elements of the plans must be in place by January 15, 2001.

Refineries and other chemical facilities are already subject to various government regulations designed to prevent chemical accidents. Cal/OSHA requires each plant to have a Process Safety Management (PSM) program. The federal and state EPA require a similar program, called a Risk Management Plan (RMP). The new county ordinance will strengthen these existing programs by giving them an increased emphasis on human factors.

The ordinance requires each employer's plan to consider human factors in five areas:

1. Process Hazard Analysis

Cal/OSHA's regulations on Process Safety Management (PSM) already require chemical plants to conduct a Process Hazard Analysis (PHA) to identify, evaluate, and control the hazards of each process. PHAs must be conducted by teams which include at least one experienced operator and at least one PHA expert. The Process Hazard Analysis must consider the consequences of failure of the existing control measures, and look at any previous incidents involving the process.

A human factors approach to PHA would study the safety consequences of:

- Operator and equipment interface
- Employee workload
- Employee work schedules, extended or unusual hours, shiftwork, and overtime
- Controls and displays
- Automatic versus manual procedures
- Operator feedback
- Labels, signs, and codes.

(continued)

2. Root Cause Incident Investigation

Human factors must be considered in investigating major chemical accidents, releases, and “near misses” that could have resulted in an accident. The county ordinance requires an approach to these investigations called “root cause analysis,” which looks at underlying sources of human error. People knowledgeable about the process must be included on Incident Investigation Teams, according to both Cal/OSHA and the county ordinance.

3. Operating Procedures

The employer must have written procedures, clearly communicated to employees, for safely conducting the activities involved in each process. Procedures should cover normal start-up, normal operation, temporary operation, emergency operation, normal shutdown, emergency shutdown, and start-up after a shutdown. Human factors should be taken into account in developing these procedures.

4. Management of Change—Staffing Cuts

The employer must expand its existing Management of Change (MOC) program to study the impact of staffing changes. MOC analysis is triggered if there will be any of the following: (a) changes in the number of positions in operations, emergency response, or safety; (b) substantive increases in their job duties; or (c) changes in their responsibilities. Before a change is instituted in these areas, the employer must evaluate its impact on safety and health.

5. Employee Training

The ordinance recommends that all employees receive introductory “awareness” training about human factors and their plant’s human factors program. Specialized training should be given to those with specific responsibilities in the human factors program, such as conducting PHAs or incident investigations. Refresher training is also required, every three years or more often if necessary.

According to the ordinance, workers and their unions must be involved in the development of the human factors program. Workers and unions should also be directly involved in carrying out each part of the program.

Lesson One Handout #2

Human Error Happens at All Levels

Human error can occur during any phase of a work process, and many different people may be responsible for it. Here are some examples.

Research and development

The chemist failed to report that the new compound expanded when it froze.

Design and engineering

The engineer failed to specify heat tracing for a heat exchanger bypass line that subsequently froze and ruptured.

Construction and installation

The contractor failed to install the specified heat tracing on a heat exchanger bypass line that subsequently froze and ruptured.

Training

The operators did not know where to turn on the heat tracing for a heat exchanger bypass line that subsequently froze and ruptured.

Operations

The operators neglected their daily check of the heat tracing, which eventually failed, allowing the heat exchanger bypass line to freeze and rupture.

Maintenance and inspection

The pipefitters failed to replace the heat tracing they pinched while repairing a flange leak, allowing the heat exchanger bypass line to freeze and rupture.

Plant management

The manager delayed activation of the heat tracing system to save energy, but unpredicted cold weather froze and ruptured several pipes and vessels.

Corporate management

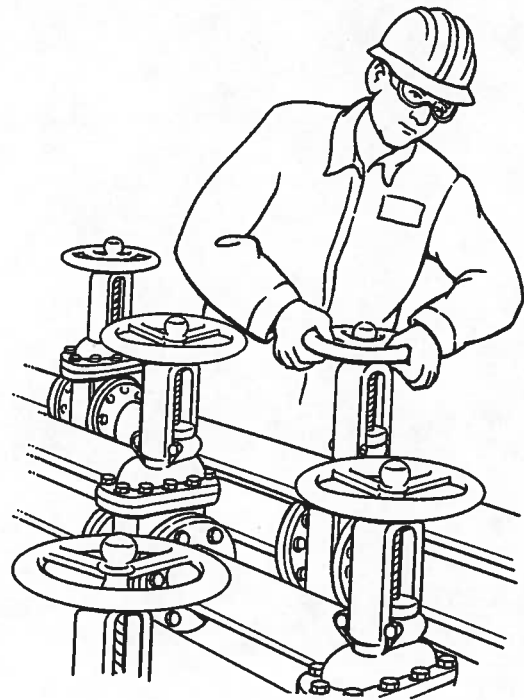
The corporate management cut the plant budget, forcing such severe staff reductions that the heat tracing was not all activated when cold weather arrived, resulting in a plant shutdown because of frozen lines.

—*Chemical Manufacturers Association, Manager's Guide to Reducing Human Errors*

Lesson One Handout #3

**Human Factors
Worksheet**

**Someone Opened
the Wrong Valve**

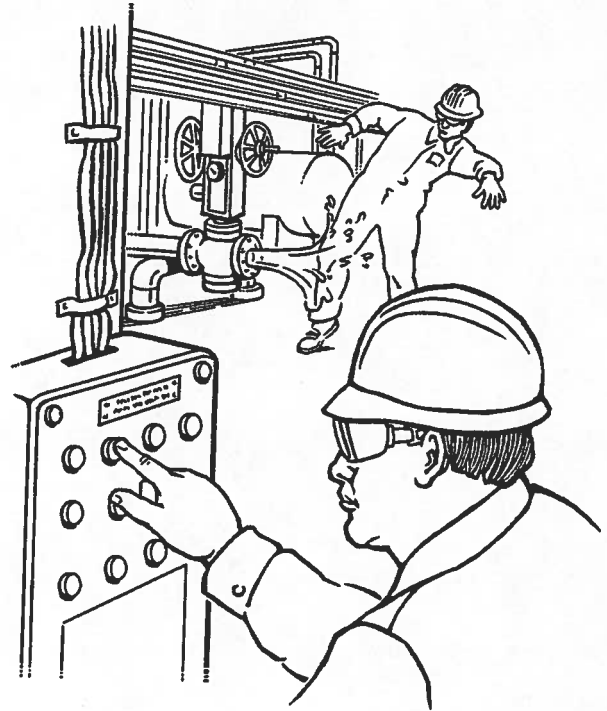


**List Possible
Underlying
Causes on Your
Flipchart Page**

Lesson One Handout #4

**Human Factors
Worksheet**

**Someone Pushed
the Wrong Button**

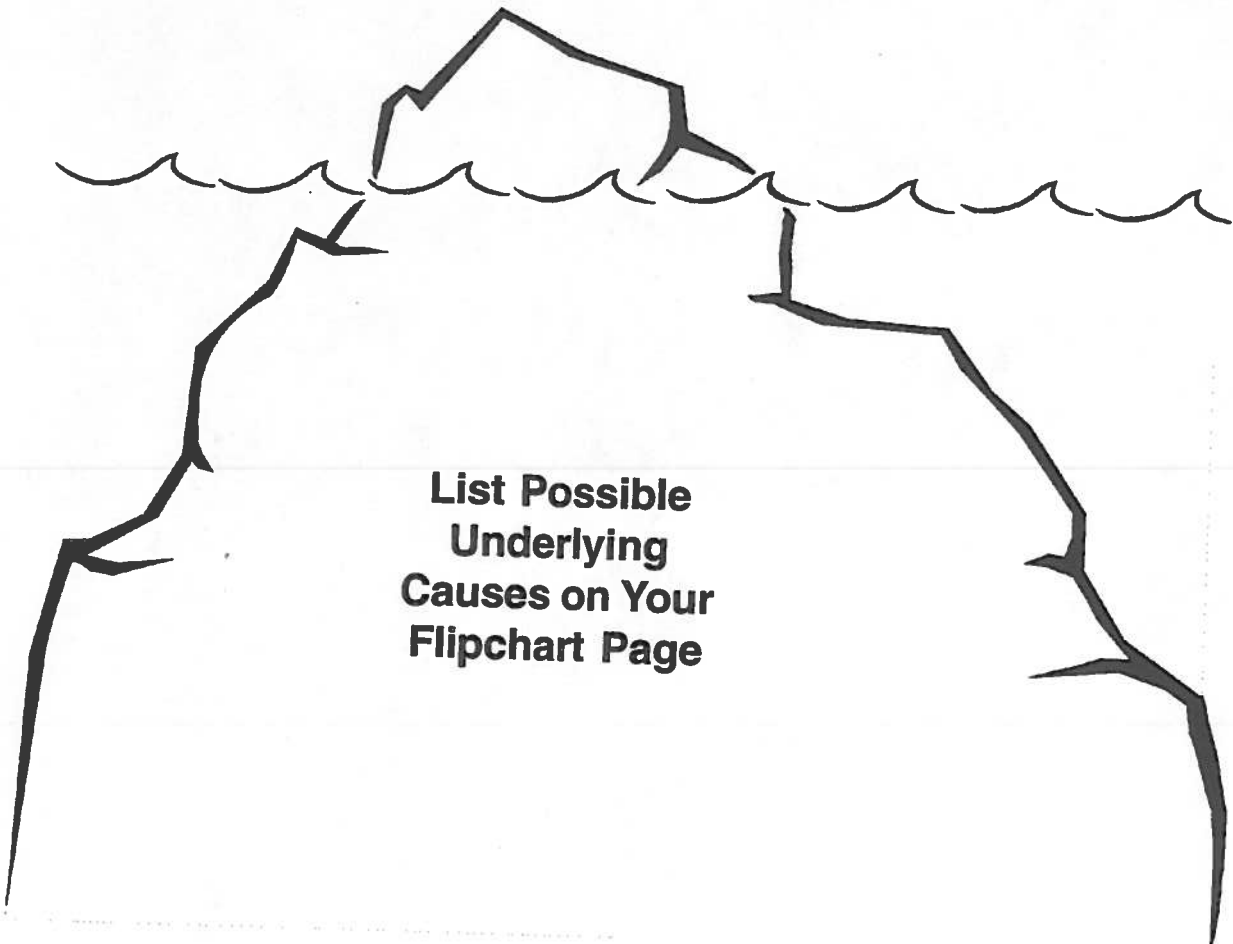
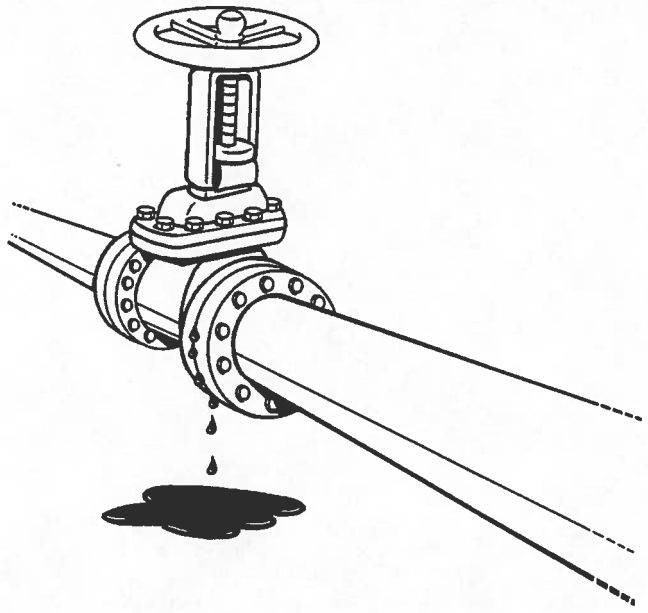


**List Possible
Underlying
Causes on Your
Flipchart Page**

Lesson One Handout #5

**Human Factors
Worksheet**

A Pipe Leaked

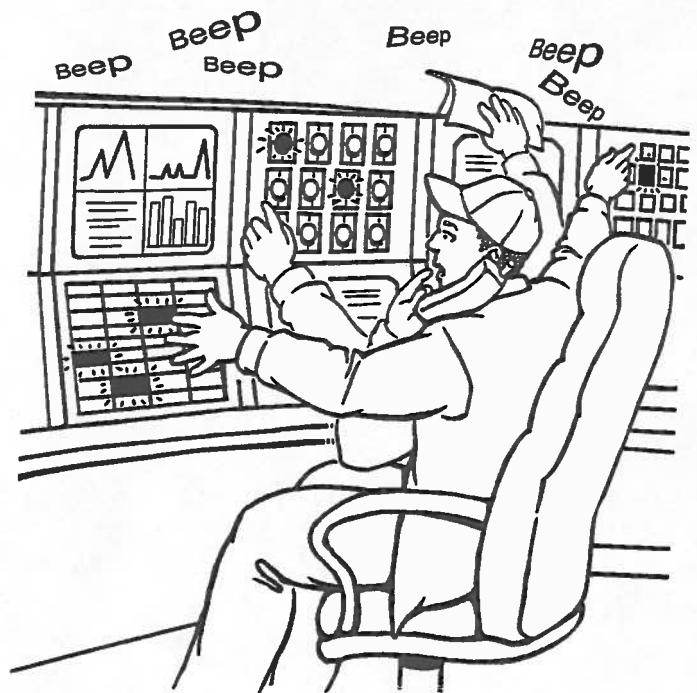


**List Possible
Underlying
Causes on Your
Flipchart Page**

Lesson One Handout #6

Human Factors
Worksheet

**Someone Didn't
Respond Properly
to an Alarm**



**List Possible
Underlying
Causes on Your
Flipchart Page**

Lessons from Major Petrochemical Incidents

The U.S. Environmental Protection Agency (EPA), the new national Chemical Safety Board, and the Contra Costa County Health Services Department conduct full investigations of major incidents to identify causes and develop recommendations to improve plant safety. The following recommendations come from actual incidents in the petrochemical industry. (See footnotes for sources of recommendations.)

Management Systems

- **Initiate review of incidents by parent company.** The parent company should develop and implement a “lessons learned” system to ensure that all incidents and near misses are fully reviewed at its level. Trade associations should also share and publicize lessons learned.¹
- **Improve plant culture.** Develop a system or plant culture that encourages management and first line supervisors to recognize potentially hazardous situations where they should exercise their responsibility and authority.⁵
- **Evaluate staffing and layoffs.** Hold a “safety summit” to allow managers and workers to evaluate the refinery’s safety needs and resources, including health and safety staffing. Develop a policy/procedure to ensure that, prior to worker layoffs, a human factors workload analysis is conducted to assure that adequate safety can be maintained with reduced personnel.⁶

Communication

- **Improve shift communications.** Develop a system to improve communications between operating shifts, first line supervisors, and management.⁵
- **Get hazard information from manufacturers and suppliers.** There must be clear communication of hazard information between manufacturers/suppliers and the refineries. Facilities should ensure that equipment manufacturers’ recommendations for proper use and maintenance of equipment are followed.³
- **Improve radio communication.**^{1,6}

(continued)

Procedures, Permits, and Training

- **Improve operating procedures.** Procedures should be revised to be more specific and to add warning statements related to the circumstances and indications of a similar incident.¹
- **Prepare for power failures.** Establish emergency shutdown procedures and instructions on what to do during an after a power failure.⁴
- **Update hot work permits.** Plants should recognize changing conditions of hot work, and should consider continuous or periodic work permit rechecks and application of PHA techniques to ensure greater control over possible changes in routine work situations.²
- **Identify vapor and ignition sources.** Develop a management system to ensure that all potential vapor sources and ignition sources are identified and controlled prior to start-up.²

Process Safety Management (PSM) Program

- **Update Process Hazard Analyses (PHAs) after incidents.** PHAs on all similar units should be updated and re-validated following a major incident. Hazards identified must then be mitigated.¹
- **Improve preventive maintenance.** Develop and maintain a written preventive maintenance program and schedule based on the manufacturer's recommendations.^{1,4} Develop a maintenance procedure to ensure that warning lights and alarms are repaired immediately.⁶ Perform a human factors evaluation of the software supporting the maintenance request procedures at the operator level.
- **Identify problem valves.** Conduct a review of valve locations throughout the refinery to identify all valves which are difficult to operate; involve operators; develop and implement engineering solutions.⁶
- **Assess control panels.** Perform a comprehensive human factors assessment of the usability of all control panels.⁶
- **Eliminate work under furnaces.** Conduct a job hazard analysis and implement improvements to eliminate the need for operators to go underneath a furnace while performing duties.

- **Assess fire controls.** Identify units where remote controls for fire isolation are difficult to assess or activate; develop alternative systems to mitigate the hazards.⁶

References

1. U.S. Environmental Protection Agency, *EPA/OSHA Joint Chemical Accident Investigation Report: Shell Chemical Company, Deer Park, Texas*. EPA 550-R-98-005, June 1998.
2. U.S. Environmental Protection Agency, *EPA Chemical Accident Investigation Report: Pennzoil Product Company Refinery, Rouseville, Pennsylvania*. EPA 550-R-98-001, March 1998.
3. U.S. Environmental Protection Agency, *EPA/OSHA Joint Chemical Accident Investigation Report: Napp Technologies, Inc., Lodi, New Jersey*. EPA 550-R-97-002, October 1997.
4. U.S. Environmental Protection Agency, *EPA Chemical Safety Alert: Hazards of Ammonia Releases at Ammonia Refrigeration Facilities*. EPA 550-F-98-017, May 1997.
5. "Investigation into the Causes of the Fire of February 23, 1999 at No. 50 Crude Unit, Tosco Avon Refinery—Preliminary Report to the Contra Costa Board of Supervisors." Contra Costa Health Services, July 28, 1999.
6. "Safety Evaluation of the Tosco Avon Refinery in Martinez, California—Draft Report to the Contra Costa Health Services." A.D. Little, Inc., April 15, 1999.

Lessons from Three Mile Island

In 1979, the Three Mile Island nuclear power plant in Pennsylvania experienced one of the most serious industrial accidents in U.S. history. The reactor went out of control and the reactor core came close to a "meltdown." Human factors experts have studied this accident in detail, and their lessons can be applied to many other industries.

Similarities to a Refinery

Many of the key parts of a nuclear reactor are familiar to refinery workers:

- Control rooms
- Automatic safety devices and alarms
- Use of cooling water
- Generators and turbines
- A workforce composed mostly of operations and maintenance workers.

A nuclear plant uses a steam turbine and generator to produce electricity. But instead of burning oil or coal to generate the steam, it uses the heat generated by a very controlled nuclear reaction. There are cooling water systems and several automatic safety devices to keep the nuclear reaction under control—preventing what's called a "meltdown."

Background on the Accident

- The plant automatically shut down after a pump failed.
- This automatically activated two parts of the safety system: the cooling water and a pressure relief valve. But there were problems with both:
 - One source of cooling water was blocked because two valves had been left in the closed position.
 - The relief valve remained stuck in an open position, so a lot of the cooling water poured out. So the reactor got hotter and hotter. More automatic cooling systems came on.

(continued)

Lesson One Handout #8

Page 2

- Some cooling systems were turned off by operators because they thought the reactor had too much water and the steam had no room to expand. It was all very complicated and confusing. No one had a clear picture of the problem.
- Finally, after about 2-1/2 hours, someone just coming onto the shift looked at the situation with fresh eyes and used the block valve to shut the relief valve. This stabilized things enough to give them time to figure out other problems. But it took a few days to completely shut the plant down.
- The reactor never opened again, although a second reactor at Three Mile Island reopened about three years later. The two reactors were identical and side by side.

Blamed on Human Error

The first set of investigations placed the blame on worker error—errors by operations and maintenance staff. Some were common errors of the type we've talked about in this workshop:

- Leaving valves in the wrong position (maintenance).
- Not following procedures or safe work practices (for example, maintenance used instrument air to clear clogged lines).
- Not diagnosing problems correctly (for example, operations didn't find the valves that were in the wrong position or the relief valve stuck in the open position, and operations wasn't able to take the right emergency action when faced with contradictory pressure and temperature readings).

A lot of simple, typical errors combined to create one of the world's most significant industrial accidents. While each of the errors weren't that unusual, the way the factors *all combined* to cause this accident was unique and totally unexpected. In fact, the set of events that occurred at was considered by the experts as simply not possible. What are the odds of so many bad things going wrong in such a short time?

Human Factors Investigations

The initial diagnosis of "human error" was sort of a rush to judgment. No one had enough information in the early days after the accident to place blame, although the government and media tried to. Investigators didn't even know the full extent of the

damage and the severity of the accident until three years later—after they had designed special remote equipment to go in and photograph the reactor core.

Human factors experts who later investigated Three Mile Island reached a very different conclusion from the earlier investigators. Three Mile Island was one of the first major industrial accidents studied using a human factors approach. Human factors experts came up with several underlying causes to explain the accident. Here are four major themes from their findings which are relevant to the oil industry.

- **Poor design of controls and the control room**

- There were too many alarms and lights. Some key lights were hidden.
- Instruments gave faulty and conflicting readings.
- An indicator light did not show actual valve position.
- The design did not allow enough time to respond.

This accident led to major changes in control room design:

- Simplified layout of controls by function.
- Priority systems for alarms.
- Real-time readouts and computer recording of readings.

- **Inadequate maintenance program and staffing**

- The maintenance program was understaffed, causing delays in inspections and repairs.
- Although operators said they periodically found valves in the wrong position, there was no system to check and report these valves.
- Pipes and valves weren't labeled, causing critical delays during the accident.
- A maintenance tag covered a critical light on the control panel during the accident.

(continued)

Lesson One Handout #8
Page 4

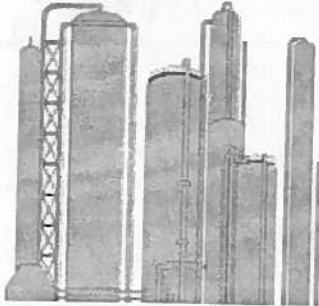
- **Inadequate training and procedures**

- Operator training stressed avoiding a different kind of problem than the one faced in the Three Mile Island accident.
- Operators were taught to “follow the rules,” not to understand the reasoning behind possible options.
- Operators later described the accident as a combination of events they had never experienced, either in operating the plant or in their training simulations.

- **Failure to learn from past mistakes**

- The original source of the accident—leaking water triggering a pump trip—had occurred at least twice in the plant during less than six months of operation.
- Pressure relief valves were predicted to periodically become stuck (2% failure rate), and had stuck open at other U.S. nuclear reactors. But this information was not shared within the industry.

REFINERY TRAINING PROGRAM



LESSON

2

Finding Solutions

Training Objectives

After completing Lesson Two, students will be able to:

- Explain the phrase “Control the hazard, not the worker.”
- List five key methods used by human factors to solve safety problems.
- Give at least three examples that illustrate how human factors tries to eliminate “error likely” situations.
- Explain how human factors matches equipment, tools, and tasks to workers’ physical, mental, and behavioral needs.
- Propose modifications to specific equipment, tools, and tasks to reduce errors and improve safety, using human factors methods.

Lesson Two at a Glance

Activity	Time	Materials
<p>1. Human factors methods.</p> <p>Instructor presents five key methods used by human factors to solve safety problems. How does human factors try to reduce the possibility of human error?</p>	25 minutes	<ul style="list-style-type: none"> ■ Flipchart and markers. ■ Overheads #1–11. ■ Handout #1.
<p>2. Small group exercise.</p> <p>Groups use human factors methods to find solutions to typical workplace safety problems.</p>	15 minutes	<ul style="list-style-type: none"> ■ Overhead #12. ■ Handouts #2–14. ■ Flipchart paper and markers for groups.
<p>3. Report back and discussion.</p> <p>Groups report their solutions.</p>	20 minutes	

Total Class Time: 60 minutes

Detailed Lesson Plan

1. Human factors methods.

(25 minutes)

The whole purpose of human factors is to find **solutions** to safety problems. In Lesson Two, we'll look at some of the methods it uses to find those solutions.

In the previous lesson, we compared human factors to traditional ideas about safety. One major difference is that human factors isn't as concerned with changing worker behavior. It believes that accidents usually result from hazardous workplace conditions, not inappropriate behavior. When a worker makes an error, human factors looks for deeper causes.

Here's a phrase that sums up how human factors solves problems:

“Control the hazard, not the worker.”

In other words, human factors focuses on hazardous conditions, and tries to eliminate them. It doesn't focus on workers' failures or shortcomings.

Instructor's Note

- Show Overhead #1, *Human Factors Methods*.

The overhead shows five key ways that human factors works to solve safety problems. It tries to:

1. Allow for differences among people.
2. Remove opportunities for error.
3. Reduce the impact of errors that do occur.
4. Design “fail-safe” systems into the operation.
5. Match the job to the worker.

We'll look at each of these in turn.

1. Allow for differences among people.

People in the workplace are different—they vary in height, weight, dexterity, reaction time, level of training, and in many other ways. Human factors recognizes that these differences must be taken into account. The workplace should be designed to enable everyone to do their job well regardless of their differences. Here's an example.

Instructor's Note

- Show Overhead #2, *The Dart Game*.

Think of a game of darts. Players are aiming at the bulls-eye. Because of different levels of experience, skill, concentration, and just plain luck, different people will have different degrees of accuracy in hitting the bulls-eye. If someone misses the target completely, you could call that a human error.

No two people will do the same task exactly the same. On the target, it's not very likely that two people will hit the same spot. In fact, one person won't throw the dart the same each time.

Human factors says systems should be designed to allow for these differences among people. We want to find a way that allows people to hit the bulls-eye despite their differences.

ASK: "How could you redesign the dart game so more people would hit the bulls-eye?"

Instructor's Note

- As people respond, list answers on a flipchart sheet. After a few minutes, show Overhead #3, *One Solution*.

One solution is to make the bulls-eye bigger. Then more people can hit it more often.

This approach might be used to design better processes or controls in a plant. For example, controls could be designed so they are easier to use by people of different heights, with different levels of strength, and with different size hands. Everyone should be able to do their job properly—to hit the "bulls-eye" easily every time.

2. Remove opportunities for error.

Sometimes the design of processes or controls is so confusing that it makes error very likely. Human factors looks for ways to make things easier to understand and use. This may require changing the design, or changing work methods.

Instructor's Note

- Show Overhead #4, *Which Stove Has Clearer Controls?*

For example, let's look at the controls on two kitchen stoves.

ASK: "Which stove has controls that are easier to understand? Why?"

Stove B has much clearer controls.

On Stove A, you don't know which control goes with which burner. You can't tell without reading the labels on the knobs.

On Stove B, controls are logically arranged and work just as you would expect. There is no need to remember how they work, or to read the labels. It's intuitive. (Labels, however, are still a useful guide.)

How many of you have a stove at home designed like Stove B? Probably not many. Why aren't more stoves made this way? Think about this the next time you have to figure out whether to push or pull a door to open it. A good human factors design tells you what to do with no need for labels or signs. That makes human error much less likely.

3. Reduce the impact of errors that do occur.

What happens if you inadvertently push the wrong button on a control panel? Depending on the design of the equipment and the work process, pushing the wrong button may cause a disaster, or do nothing at all. Human factors can't always stop human error, so it tries to make the consequences of error less serious.

Here's an example. In Lesson One, we noted the two most serious nuclear power plant accidents in history—at Three Mile Island in Pennsylvania in 1979, and at Chernobyl in the Ukraine in 1986.

Instructor's Note

- Show Overhead #5, *Two Accidents—Different Results.*

The overhead shows the two plants. Both reactors approached a “meltdown” and produced a great deal of radiation. But Chernobyl released a lot more radiation into the environment than Three Mile Island. This radiation harmed people, crops, and animals throughout Russia and Scandinavia.

The difference is in the design of the two facilities. At Three Mile Island, all components of the reactor and cooling water system are enclosed in huge concrete structures known as containment domes. The walls of each containment dome are 12 feet thick, and are reinforced with high-strength steel. The dome is designed to withstand the direct impact of a jet airliner, and it can withstand extremely high pressures from within as well.

In the Three Mile Island picture, notice the two containment domes in the center foreground (directly in front of one of the big cooling towers at the rear of the picture). These containment domes prevented radiation from escaping during the accident.

The Chernobyl plant, however, is of a different design and has no containment domes. It was much easier for radiation to escape.

Plant design can make a big difference. Human factors looks for safer designs that can limit the impact of human errors and accidents.

4. Design “fail-safe” systems into the operation.

Human factors also looks for “fail-safe” designs that can **prevent** people from making an error.

Instructor's Note

- Show Overhead #6, *Don't Open the Door!*

ASK: “What happens when a microwave oven is running and you try to open the door?”

Either the door won't open or the microwave automatically shuts off. Otherwise you could be exposed to radiation. We all know we

shouldn't open the door of a microwave when it's running, but sometimes we forget and do it anyway.

This fail-safe feature is built into the design of the microwave. It's automatic and you don't have to think about it. It's a lot more effective than a warning label would be.

Human factors says that controls in a plant should work the same way. They should be designed so mistakes are difficult or impossible to make.

ASK: "What are some examples of 'fail-safe' design in a refinery?"

Instructor's Note

- Let volunteers give brief answers.

5. Match the job to the worker.

Human factors tries to match equipment, tools, and tasks with the capabilities, limitations, and needs of workers.

Instructor's Note

- Show Overhead #7, *Put the Worker at the Center*.

This is another example of how human factors reverses traditional thinking. In the traditional workplace, the worker is expected to adapt to the equipment, tools, and tasks that are already there. But human factors turns that around. It puts the worker at the center, and says that equipment, tools, and tasks should be designed to meet the worker's needs.

In other words, human factors tries to make the plant "user friendly."

Human factors says that equipment should be **designed for human use**. That idea has applications both in our everyday lives and in the workplace.

Think about things you use in your daily life. Some people can't figure out their VCR. Some people get serious wrist problems from the awkward, repetitive motions involved in using a computer mouse. These everyday items are often not "designed for human use."

Human factors asks whether equipment is designed to meet people's natural capabilities and limitations (physical, mental, and behavioral). Many of you will recognize this as the field called **ergonomics**. Ergonomics is one part of human factors.

Next, let's look at some pictures that illustrate the importance of matching the job to the worker.

ASK: "What problems do you see in this picture?"

Instructor's Note

- Show Overhead #8, *What Problems Do You See?*
- As people call out problems, use a non-permanent marker to circle the area of each one on the overhead.

Possible answers include:

- The valve is too high, so the worker has to stretch to reach it.
- The valve is awkwardly placed and behind a barrier. The worker could get hurt reaching for the valve, or might have trouble reaching it quickly in an emergency.
- The valve seems hard to turn.
- The valve doesn't appear to be clearly labeled.

ASK: "What suggestions could you make to improve this situation?"

Possible answers include moving the valve lower and making it easier to reach. Make it easy to turn. Label it clearly.

This example illustrates why good design is more important than just training workers to use proper techniques. With the operation designed like this, the worker is **forced** into an awkward position. Instead, equipment needs to be adapted to meet the **physical** capabilities of the worker.

Instructor's Note

- Show Overhead #9, *What Time Is It?*

Human factors also looks at **mental** capabilities. Here is another example of poor design.

ASK: “According to this clock, what time is it?”

The clock reads about 10:08. Notice it took longer to figure out the time because it is not a regular clock. Most people would have trouble reading this clock.

The clock illustrates a basic principle of human factors—the workplace should be designed to match our knowledge of everyday things. Equipment should work the way we expect it to.

Instructor's Note

- Show Overhead #10, *Stress and Fatigue*.

In addition to physical and mental capabilities, human factors looks at other issues like stress, fatigue, and motivation. These are usually grouped together as **behavioral** issues.

Imagine that it is 3 am, a worker has worked 11 days straight and is exhausted. Suppose there were an emergency. Suddenly there are lights flashing and alarms sounding.

ASK: “How could this contribute to mistakes?”

Possible answers include:

- The worker's reaction time would probably be slower. Fatigue can impair the ability to react quickly. Even if the worker were not fatigued, the body's natural rhythms slow down during late-night hours.
- Also because of fatigue and the late hour, the worker could become confused or disoriented more easily.
- The worker could forget proper procedures.
- The worker might not be alert because of boredom.

See Handout #1 in your binder for more information on these topics.

ASK: “We have now looked at all five of the key human factors methods. Can you remember what they are?”

Instructor's Note

- After the class responds, show Overhead #11, *Human Factors Methods—Review*.

Human factors tries to:

1. Allow for differences among people.
2. Remove opportunities for error.
3. Reduce the impact of errors that do occur.
4. Design “fail-safe” systems into the operation.
5. Match the job to the worker.

2. Small group exercise.

(15 minutes)

How does human factors find solutions to safety problems?

Remember that all the methods we've studied can be summed up in one phrase: **“Control the hazard, not the worker.”**

To see how this phrase can be applied in practice, we're going to do an exercise in small groups. We'll use human factors methods to propose solutions to some typical workplace safety problems.

Instructor's Note

- Show Overhead #12, *Looking for Solutions*.

Each group will be assigned **one** of the workplace scenarios shown on this overhead. There are larger versions of the pictures and more details on the three worksheets (Handouts #2–4) in your binder.

In your group, turn to the worksheet that you're assigned, look at the picture, read the caption, and think about the scenario. Then:

- **Identify the problem or problems.** What is unsafe in the picture? How could this lead to human error or an accident?
- **Develop solutions.** Your group should “brainstorm” about possible solutions you would propose for these problems. There will probably be many possible solutions.

Your group will be given a large flipchart sheet to use when you report back to the class. Choose someone in your group to record your answers on this sheet as you work. They should list both the problems you identify and your proposed solutions. Also choose someone to present and explain these answers to the class later.

In developing your solutions, try to use some of the principles we've talked about, such as allowing for individual differences, removing opportunities for error, and matching the job to the worker. In other words, you'll want to propose **redesign** of equipment, tools, or tasks.

Try to come up with your own solutions first. After you discuss solutions for a while, you may want to turn to the factsheets in your binder (Handouts #5–14) for more ideas. Your worksheet lists the factsheets that are most relevant to your scenario, although other factsheets may also have useful information. The points marked with a check (✓) in the factsheets will be most important in developing your solutions. You'll have about 15 minutes.

Instructor's Note

- Divide the class into groups of 5 or 6 people each.
- Assign **one** of the three worksheets (Handouts #2–4) to each group. (It's OK to assign the same worksheet to more than one group.)
- Ask the groups to identify **problems** in their picture first, and then propose **solutions**.
- Give each group a blank flipchart sheet. Ask them to choose someone to record their problems and solutions on this sheet as they work.
- Also ask each group to choose someone to give their report to the class later.
- Suggest that the groups refer to the factsheets (Handouts #5–14) for ideas, but only after they have tried to come up with solutions themselves. Each worksheet indicates which of the factsheets are most relevant to their scenario.
- Circulate among the groups as they work to make sure they are on track and to answer any questions.

3. Report back and discussion.

(20 minutes)

Instructor's Note

- Bring the class back together.
- Show Overhead #12, *Looking for Solutions*, again and leave it on the screen while the groups report.
- Have all the groups post their completed flipchart sheets at the front of the class.
- In turn, ask each group's designated person to report. Using the flipchart and the picture on the overhead, they should first list the problems the group identified. Then they should explain the group's solutions. Ask them which factsheets had the most relevant information. Others in the group can add to the report if they wish. Allow time for the class to discuss the answers.
- For ideas, see the *Instructor's Discussion Guide* below.

Instructor's Discussion Guide

Listed here are key safety problems in each scenario, with a few possible solutions. Remember that groups may propose solutions which are not shown here, but which are equally valid.

The Exit Sign (most relevant factsheet: Handout #5)

Problems

- The sign is confusing. There are two conflicting directions.
- People would not understand the procedure for escape.

Solutions

- Make the sign easy to understand.
- Give workers training on emergency exit procedures, including escape routes and signs. Provide written instructions and conduct walkthrough drills.

The Racket (most relevant factsheets: Handouts #10 and 12)

Problems

- The noise level may be so distracting that the worker doesn't perform the task safely.
- Because of the discomfort, the worker may be eager to leave the area and therefore take shortcuts.
- The worker may not be able to hear alarms, shouts, or other communications.
- Noise can cause hearing loss.

Solutions

- Reduce the noise level through changes to plant and equipment. (For example, eliminate the source of the noise, or install better insulation and soundproofing.)
- Study procedures conducted in noisy environments to find ways to reduce the hazards. (For example, reduce the number of workers who must enter noisy areas, how frequently they must enter, and how much time they must spend there.)
- Find better means of communication to use in noisy areas.
- Use a "buddy system" (with a standby worker outside) when someone must enter a noisy area.
- Train workers regularly on safety issues such as noise, lighting, heat, and ergonomics. Include a warning that they should take extra care when working in noisy environments because of the chance of distraction.

The Emergency (most relevant factsheets: Handouts #7, 8, 9, and 13)

Problems

- Because the system is highly automated, the operator may have lost skills needed to analyze and act on the emergency (deskilling).

- The operator may not be trained to handle the emergency. (For example, he may never have practiced using manual control.)
- The system seems to have no “leading indicator” to give the operator advance warning that something is going wrong. “All hell broke loose” in an instant.
- Fatigue may prevent the operator from responding properly.
- The operator may be bored after hours of inactivity, reducing attentiveness and reaction time.
- There may not be enough backup operators to properly handle the emergency.
- Multiple lights and alarms may cause confusion and make it difficult to analyze the problem quickly.

Solutions

- Preserve operator skills in automated plants. (For example, practice running under manual control occasionally.)
- Keep operators trained on how the whole system works.
- Provide “leading indicators” to give operators adequate advance warning when something is going wrong.
- Avoid work schedules that can cause fatigue.
- Find ways to avoid periods of inactivity. Keep operators involved and give them something to do.
- Provide enough backup operators to handle upset conditions.
- Make control panels and alarms easy to understand. (For example, reduce the number of controls and find a way to suppress “nuisance” alarms.)

This wraps up Lesson Two. We have looked at several methods that human factors uses to come up with recommendations for change. In Lesson Three, we’ll use human factors methods to analyze some actual refinery situations.

Lesson Two

Overheads



In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Human Factors Methods

Human factors works to improve job safety. Its approach is to eliminate situations where errors are likely to happen. It doesn't try to modify individual behavior. The aim is to "control the hazard, not the worker."

Human factors tries to:

1. Allow for differences among people.
2. Remove opportunities for error.
3. Reduce the impact of errors that do occur.
4. Design "fail-safe" systems into the operation.
5. Match the job to the worker.



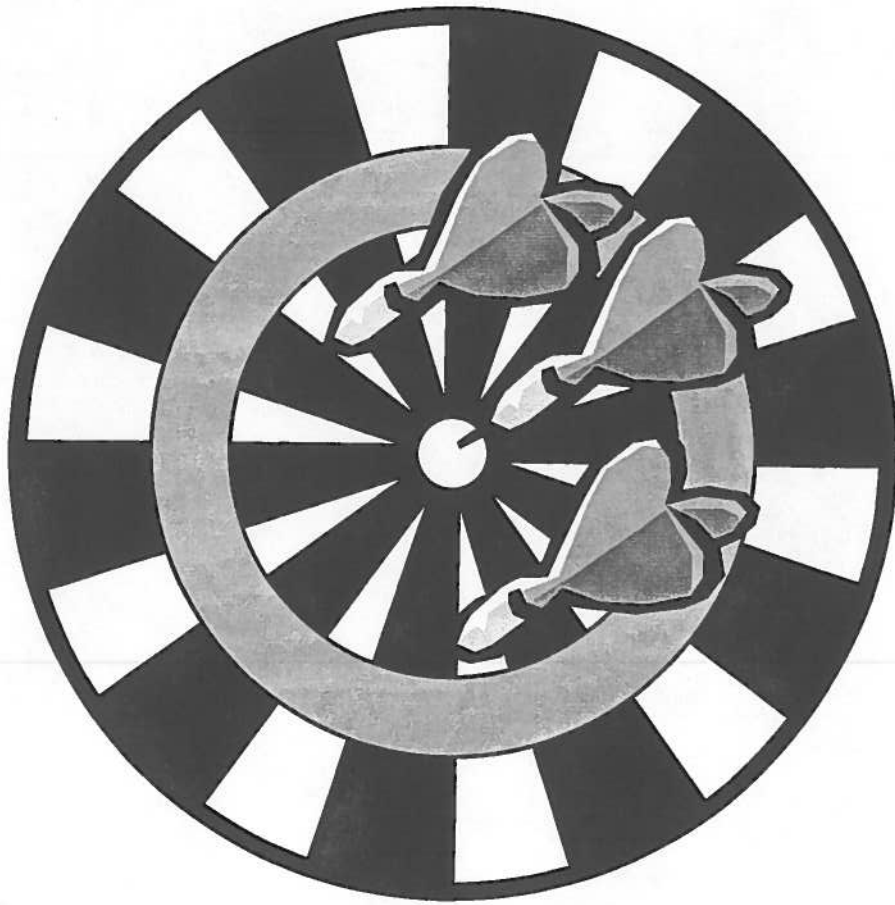
In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Lesson Two Overhead #2

**1.
Allow for
Differences**

The Dart Game





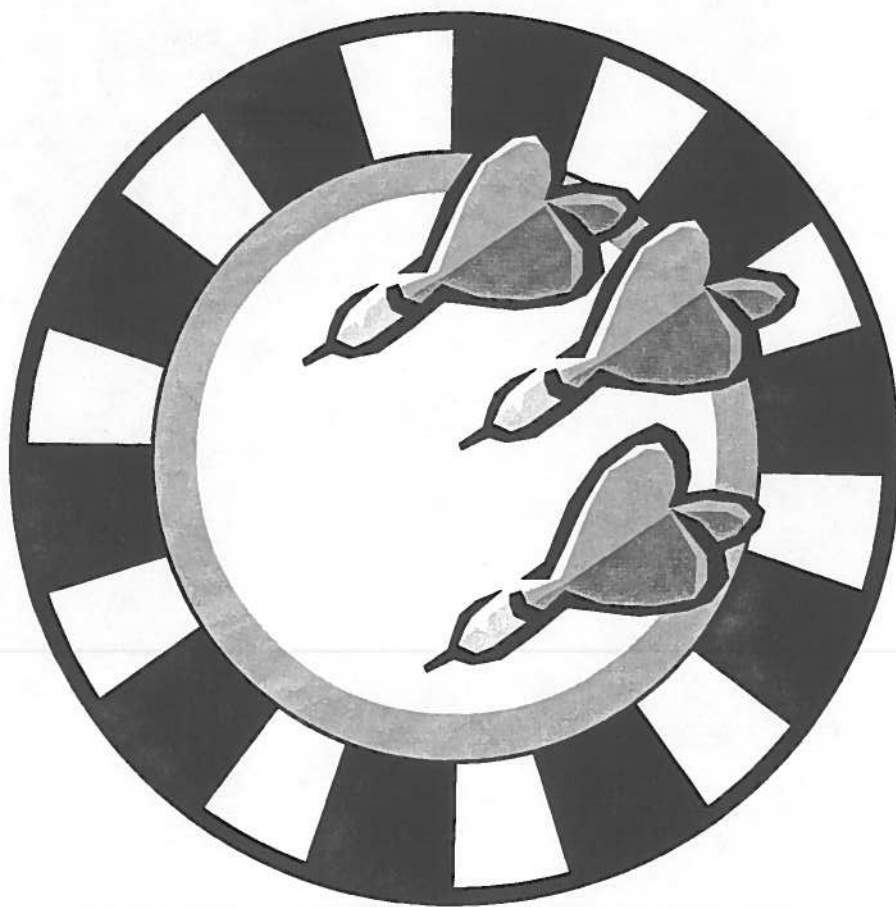
In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Lesson Two Overhead #3

**1.
Allow for
Differences**

One Solution





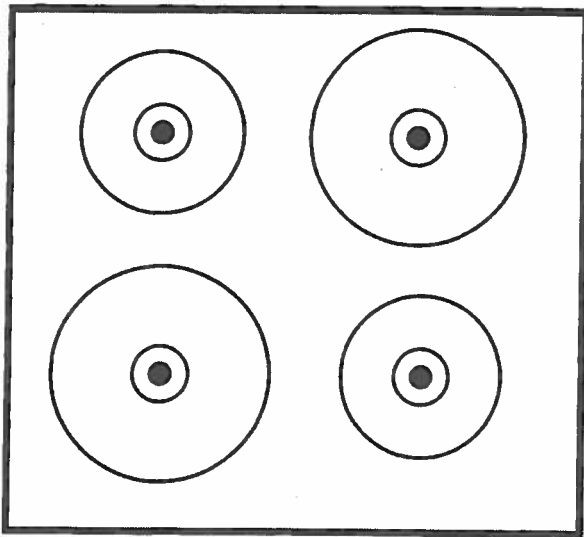
In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Lesson Two Overhead #4

2.
Remove
Opportunities
for Error

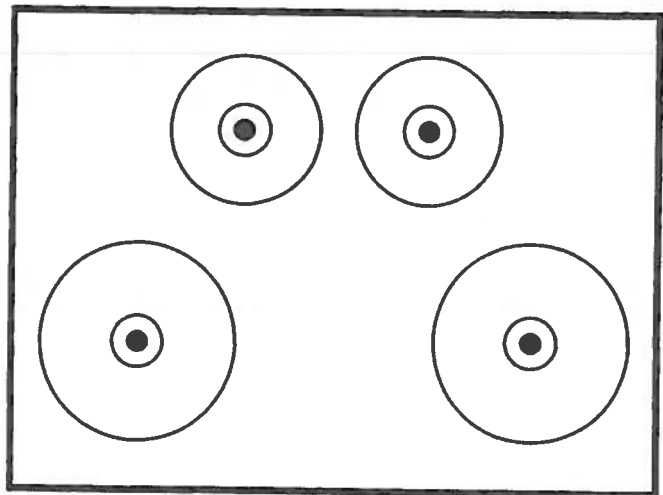
Which Stove Has Clearer Controls?



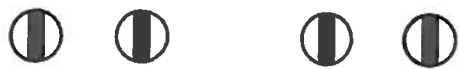
STOVE A



Back Left Front Left Back Right Front Right



STOVE B



Front Left Back Left Back Right Front Right



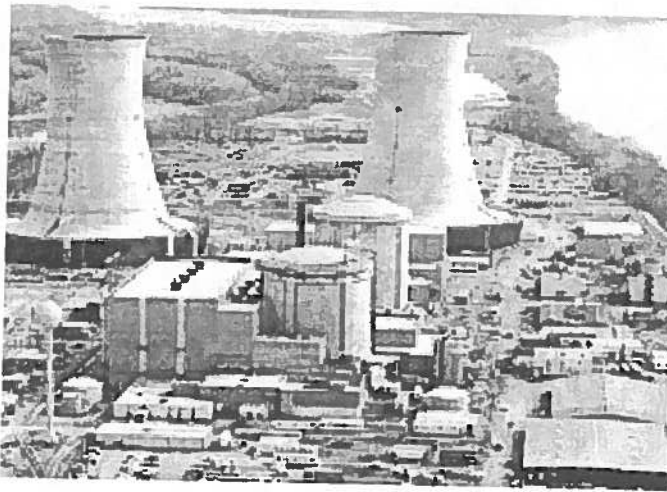
In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Lesson Two Overhead #5

**3.
Reduce
the Impact
of Errors**

Two Accidents— Different Results



Three Mile Island



Chernobyl



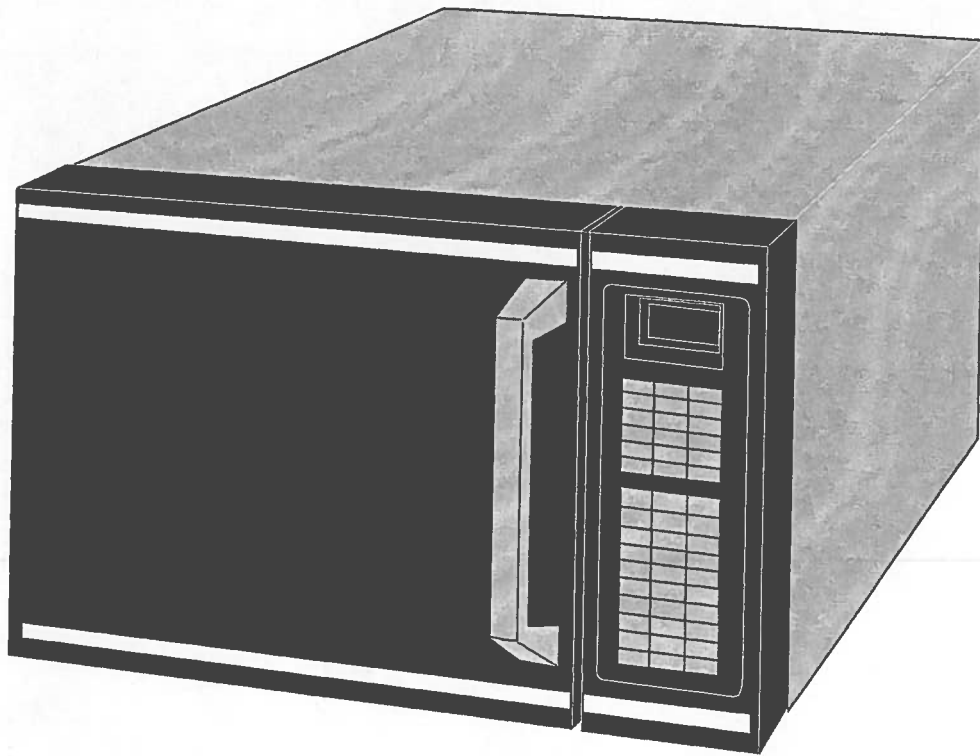
In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Lesson Two Overhead #6

**4.
Use
Fail-Safe
Systems**

**Don't Open
the Door!**





In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Lesson Two Overhead #7

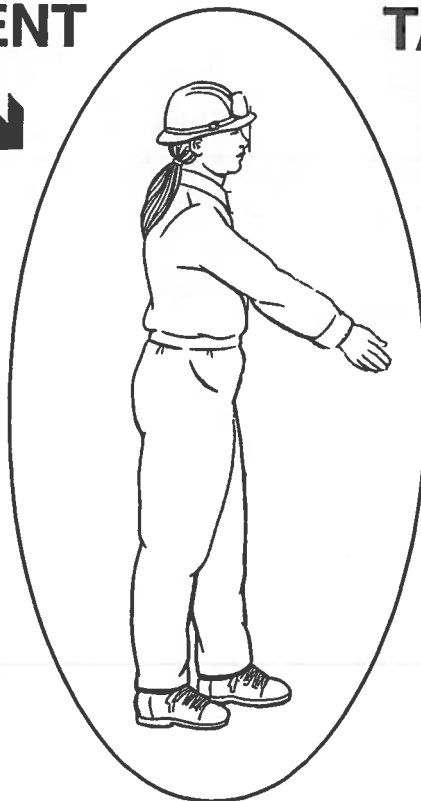
5.
Match the
Job to
the Worker

Put the Worker at the Center

EQUIPMENT



TASKS



TOOLS

Human factors makes the plant “user friendly.”



In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Lesson Two Overhead #8

5.
Match the
Job to
the Worker

What Problems Do You See?



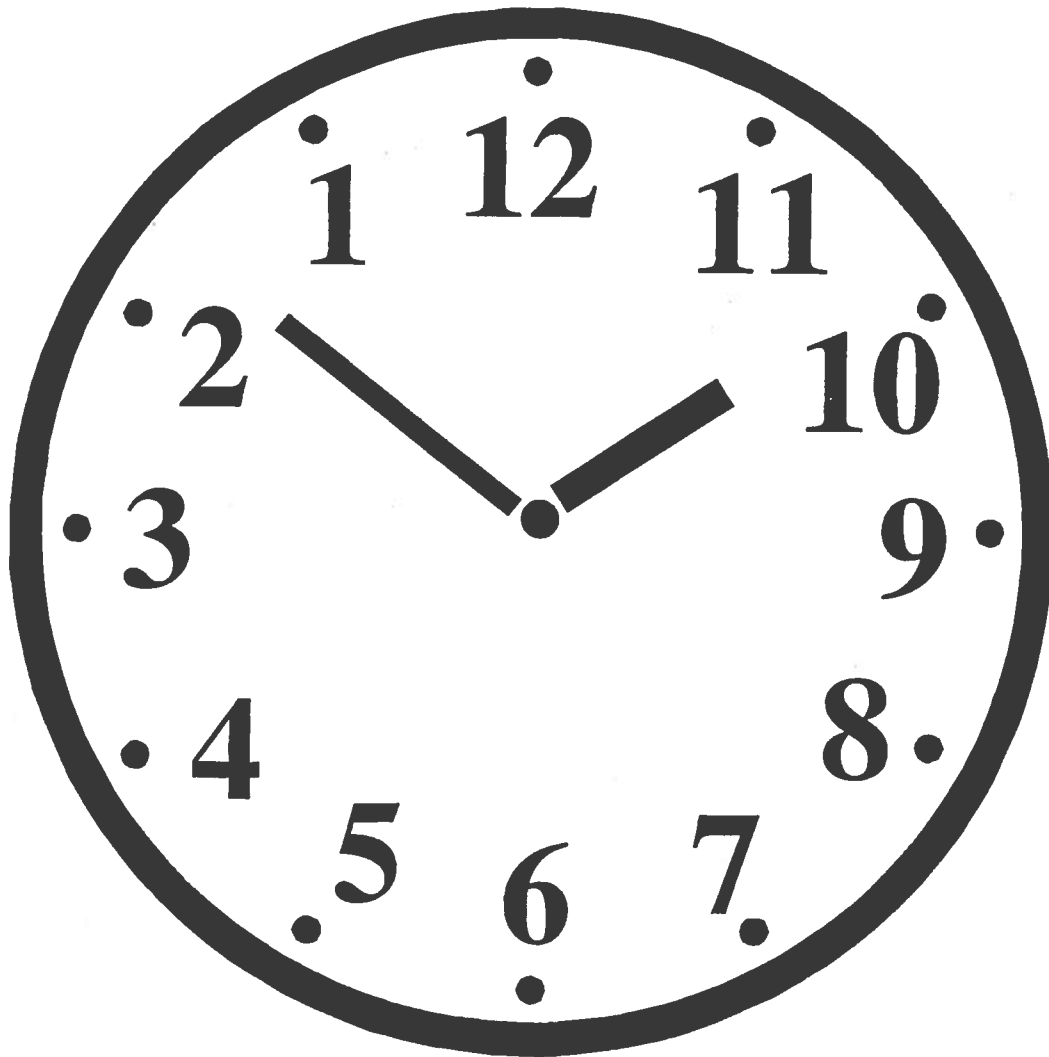


In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

5.
Match the
Job to
the Worker

What Time Is It?



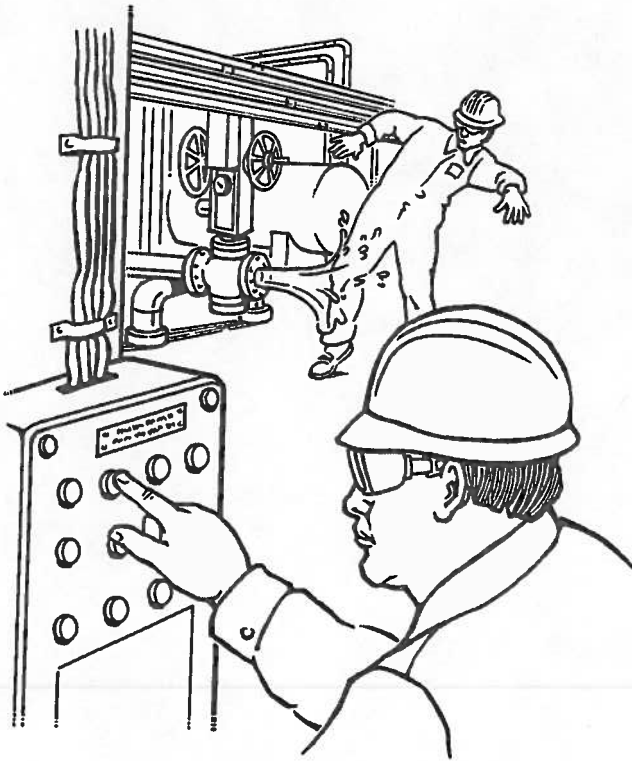


In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

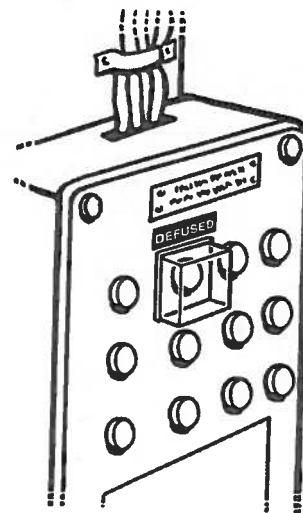
✓ **Controls should be difficult to operate by accident.**

Lock out or defuse controls that could cause serious problems if they were engaged by mistake.



**SWITCH ENGAGED
BY ACCIDENT**

**SWITCH
DEFUSED**



Human Factors
Factsheet

The Physical Work Environment

Traditional safety specialists are mainly concerned with preventing physical harm to the worker. Human factors considers both physical and mental effects.

When human factors specialists talk about exposure to noise, poor lighting, heat, or cold, they are usually considering the impact on an operator's ability to carry out a task. For example, these hazards may cause anxiety or fatigue, thus reducing performance.

✓ **Consider OSHA standards as only minimum requirements.**

Federal and state OSHA set standards regulating some hazards in the physical work environment (including noise and lighting). However, human factors may be concerned about these hazards even when levels meet OSHA requirements. OSHA standards are designed to protect workers from physical harm, but human factors has a broader concern for **all** conditions that may lead to human error. For example, workplace noise may be within OSHA limits but still distract workers enough that they make mistakes.

NOISE

Sometimes it's so noisy that "you can't hear yourself think." Noise can increase human error. It may:

- Mask warning sounds like alarms and shouts.
- Increase fatigue.
- Make it harder to mentally "process" complex information.
- Distract workers so they don't pay attention to other things that are happening.
- Make it harder to monitor and interpret events.



(continued)

LIGHTING AND GLARE

Poor lighting and glare can make it hard to see what you are doing. Workers may not be able to read valve labels or displays on the control panel. In the field at night, poor lighting may make it nearly impossible to read instruments.

HEAT AND COLD

Extreme heat and cold can cause workers to experience fatigue and loss of concentration. They may miss a step in a procedure, especially if they rush to complete tasks.

Cold can also affect muscle control, reducing dexterity and strength.

When working in extreme heat, workers should first be **acclimated** (given enough time to get used to working in heat). Otherwise they are affected more adversely by the heat.

—Center for Chemical Process Safety

Human Factors
Factsheet

Automated Control Systems

Automation may reduce some safety problems while creating new and more complex hazards. It is often seen as a way to reduce human error, and as a way for companies to get the technological lead over competitors. But most automated systems design ignores human factors principles. Here are some issues to consider with automated control systems.

✓ **Preserve operator skills in automated plants.**

By taking away the easy parts of an operator's task, automation can make the difficult parts even more difficult. Once a process is automated, operators have less practice using the controls and lose their "mental picture" of how the whole system works. During an upset, it's harder for them to determine what is going on and how to respond. This has happened on airplanes where the crew was so reliant on automated systems, they didn't know how to take control when there was a system failure. The planes crashed. Now airplane control systems balance automation with preserving pilot skills.

✓ **Use understandable displays.**

Operators can become confused about what an automated system is doing or what mode it is presently in. This makes it difficult for the operator to determine the appropriate response. The system may hide information from the operator, or display information in an unexpected sequence. For example, forcing the operator to view one screen at a time limits the operator's ability to see related information needed to analyze the situation.

✓ **Provide enough operators to handle upset conditions.**

Advanced computer control systems can increase workload as well as stress and anxiety. Human factors consultants to the refining industry compared operator activities during routine and upset conditions. They concluded that, in an automated plant, workload more than doubled during upset conditions. Without staffing for upset conditions, operators in an automated plant become overloaded and overwhelmed.

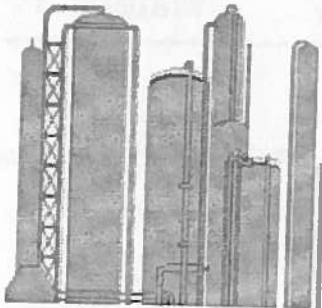
—Source: James Reason, *Managing the Risks of Organizational Accidents* and Beville Engineering, *Changes in Operator Activities Due to Upsets*.

Management Commitment

✓ Make sure management does its job.

According to the Center for Chemical Process Safety (CCPS), one of management's top priorities should be reducing human error and maintaining a safe environment. The following management attitudes, policies, and practices are crucial parts of this effort. Management should:

- **Demonstrate a commitment to safety.** This should start at the very top of the organization.
- **Establish a blame-free atmosphere.** This will encourage employees to report problems and give other feedback that may be essential for identifying and reducing risks.
- **Provide resources.** Human factors experts should be used to guide efforts to improve process design, operation, and maintenance. The necessary funds and personnel should be made available.
- **Promote understanding of human factors principles.** Employees throughout the organization should understand the basics of human factors so they can help apply these ideas.
- **Eliminate situations where errors are likely.** Use human factors techniques and expertise to identify and eliminate high-risk conditions.



Applying Human Factors to Refineries

Training Objectives

After completing Lesson Three, students will be able to:

- Define latent conditions.
- List the four types of latent conditions, and give examples of each type.
- Describe the purpose and use of the County Latent Conditions Checklist.
- Apply their understanding of latent conditions to real life problems in refineries.
- Explain the need for a comprehensive plan to eliminate latent conditions.

Lesson Three at a Glance

Activity	Time	Materials
<p>1. The four types of latent conditions.</p> <p>Defining latent conditions—hidden safety hazards that might cause future accidents. Human factors divides them into four categories. In a plant, all four need to be identified and corrected.</p>	10 minutes	<ul style="list-style-type: none"> ■ Flipchart and markers. ■ Overheads #1–5.
<p>2. The County Checklist.</p> <p>Brief overview of Contra Costa County’s new Latent Conditions Checklist.</p>	5 minutes	<ul style="list-style-type: none"> ■ Handout #1.
<p>3. Refinery case studies.</p> <p>Small groups study actual refinery incidents and suggest latent conditions that may have contributed to them. Groups use the Latent Conditions Checklist as an aid.</p>	15 minutes	<ul style="list-style-type: none"> ■ Overhead #6. ■ Handouts #1–2. ■ Flipchart paper and markers for groups.
<p>4. Report back and discussion.</p> <p>Groups report their answers, and the class discusses them. Class evaluates usefulness of the Checklist.</p>	20 minutes	
<p>5. Using a checklist.</p> <p>Instructor explains guidelines for using any latent conditions checklist.</p>	5 minutes	<ul style="list-style-type: none"> ■ Overheads #7–8.
<p>6. Recommending solutions.</p> <p>After latent conditions are identified, the next step is to recommend and implement solutions.</p>	5 minutes	<ul style="list-style-type: none"> ■ Overhead #9. ■ Handout #3.

Total Class Time: 60 minutes

Detailed Lesson Plan

1. The four types of latent conditions.

(10 minutes)

Instructor's Note

- Show Overhead #1, *The Human Factors Method*.

Earlier in this workshop, we saw that human factors uses two major techniques. It studies accidents to find their causes, and it studies the workplace to find hazardous conditions that might cause the next accident.

We have already covered the ideas and terms that human factors uses in studying **accidents** and **"near misses."** In this lesson, we will look at how human factors studies the **workplace**. We'll introduce a few new terms, and we'll practice using some tools that human factors provides to help identify workplace hazards. Finally, we'll see how human factors comes up with recommendations for change, and how to increase the chances that these recommendations are actually carried out, not filed away and forgotten.

First, let's review some ideas from the previous lessons. When human factors investigates an accident, it tries to find the most basic causes. **Direct causes** (like human error) are just surface level causes. Deeper down, there are **underlying causes** and **root causes**. Finding and correcting these deeper causes helps prevent future accidents.

There are also underlying safety hazards that have **not** been involved in an accident yet, but might cause human errors, accidents, or injuries in the future. To improve safety, these conditions need to be identified and corrected too. This is the **proactive** side of human factors. It tries to find problems **before** there is an accident.

However, since these underlying hazards may be "hidden," they can be difficult to find in a safety inspection.

Human factors uses the term **latent conditions** to refer to hazards of this type (whether or not they have actually caused an accident).

Instructor's Note

- Show Overhead #2, *Latent Conditions*.

Notice that we're using the iceberg again. Because latent conditions are hidden, we put them below the water line.

Here are the most important points about latent conditions:

- They are hidden safety hazards that might contribute to the next accident.
- "Latent" means "hidden" or "present, but not yet detected."
- They are "accidents waiting to happen."
- They often involve weaknesses in plant design, safety systems, or management.
- They are directly related to human error, because they make it harder for people to do their jobs well and they make mistakes more likely.

Instructor's Note

- Show Overhead #3, *Examples of Latent Conditions*.

Here are some examples of latent conditions:

- Poor design of processes and equipment
- Lack of clear labeling
- Inadequate operating procedures
- Poor layout of indicators and controls
- Equipment that is in an unsafe location or difficult to access
- Lack of inspection and preventive maintenance
- Inadequate training for normal and emergency situations
- Fatigue due to long hours or late hours
- Inadequate staffing levels.

Notice that these are the same conditions we looked at previously when we discussed the underlying causes of accidents. The terms “underlying cause” and “latent condition” are very close in meaning. As a rule of thumb, think of “underlying cause” as a term that’s used in accident investigations (involving something that’s already happened), and “latent condition” as a term that’s used in workplace safety inspections (trying to prevent future problems).

How do we make sense of all these latent conditions? We need a systematic way to identify which unsafe conditions may exist in a plant. Human factors organizes latent conditions into these four categories:

1. Operator Characteristics
2. Task Characteristics
3. Physical Environment and Workplace
4. Organization and Management Factors.

This is the human factors “four point approach” to safety.

Instructor's Note

- Show Overhead #4, *Four Point Approach to Safety*.

This diagram illustrates the four categories and shows how they fit together. Remember that hazards in any category can be a source of human errors or accidents. Considering the four categories together allows us to get a comprehensive look at the whole operation rather than focusing narrowly on its separate parts.

Let’s look at these categories more closely and see what kind of latent conditions fall in each one.

Instructor's Note

- Show Overhead #5, *Categories of Latent Conditions*. In turn, ask the following four questions and let the class answer. Write their answers on the overhead (using a non-permanent marker) or on the flipchart. Compare the class responses to the suggested answers below each question.

ASK: “What are some examples of latent conditions that might fall under **operator characteristics**?”

Possible answers include problems related to:

- Worker experience and knowledge
- Stress and fatigue
- Physical strength.

ASK: “What are some examples of latent conditions that might fall under **task characteristics**?”

Possible answers include problems related to:

- Difficulty or complexity of the task
- Training
- Adequacy of operating procedures (written or unwritten)
- Conflicts between policy and practice (shortcuts).

ASK: “What are some examples of latent conditions that might fall under **physical environment and workplace**?”

Possible answers include problems related to:

- Equipment design
- Location of equipment and access to it
- “User friendliness” of controls
- Physical environment: lighting, heat, noise, vibration
- Personal protective equipment.

ASK: “What are some examples of latent conditions that might fall under **organization and management factors**?”

Possible answers include problems related to:

- Staffing, scheduling, overtime, and workload
- Safety culture and attitude
- Management system: authority, accountability, commitment, procedures, rewards and punishments, budget, communication
- Ability and willingness to learn from past accidents.

These categories are not rigid. There is a lot of overlap among them. They are intended only as a useful aid to thinking systematically about safety. In fact, it might be correct to put almost all the latent conditions we're discussing into the last category (organization and management factors) since management has the ultimate responsibility for preventing accidents and making the workplace safe.

2. The County Checklist.

(5 minutes)

As we discussed before, Contra Costa County has passed a new industrial safety ordinance (ISO 98-48). It requires refineries to develop safety programs with an emphasis on human factors. Along with the ordinance, the County has issued a Latent Conditions Checklist.

The Checklist is a tool to help refineries identify and eliminate latent conditions. It can be used either in accident investigations or in general workplace inspections.

You'll find a condensed version of the Checklist in your binder as Handout #1. Take a look at it now. For the purposes of this workshop we've shortened it, but our version can still give you a good idea of how it's organized. To get the complete Checklist, contact your plant's human factors committee, safety committee, or Contra Costa Department of Health Services, Hazardous Materials Programs.

Page 1 of Handout #1 is a Table of Contents that shows how the Checklist is organized. Notice that it divides latent conditions into the same four categories we have been discussing:

1. Operator Characteristics
2. Task Characteristics
3. Physical Environment and Workplace
4. Organization and Management Factors.

The Checklist has a series of questions in each category. Each category is divided into several sub-categories. This system can help you identify possible latent conditions. It is similar to a safety

inspection of the plant, but the inspection focuses on human factors issues. Refineries and other plants covered by the ordinance are required to identify latent conditions by this method.

Look at Page 2 of Handout #1, which is called "Using the Checklist." We'll come back to this later. For now, just notice that for each item on the Checklist, you enter **Y** (yes), **N** (no), or **NA** (not applicable). The note at the bottom of Page 3 of the handout explains in detail what these terms mean: **Y** means the issue has already been addressed and isn't a problem, **N** means the issue has not been addressed and recommendations for correction should be made, and **NA** means that the issue doesn't apply to this part of the plant.

Here are just a few examples of issues the Checklist covers.

Instructor's Note

- Select one or two questions in each category on the Checklist (Handout #1) to use as examples. Have the class follow along in Handout #1 as you read the questions you have chosen.
- It's not important which questions you choose. The purpose is simply to introduce the class to the style and organization of the Checklist.

3. Refinery case studies.
(15 minutes)

Instructor's Note

- There are five Case Studies available in Handout #2. Select **three** of the five to use in this session. Case Studies One, Two, and Three will be of most interest to refinery operators, and Case Studies Four and Five will be of most interest to refinery maintenance workers.

Now we'll break into small groups to practice identifying and evaluating latent conditions, using the Checklist (Handout #1) as a tool.

Handout #2 in your binder has a number of Case Studies describing “real life” refinery incidents. You will be assigned **one** of the Case Studies to discuss in your group. Your task is to identify the latent conditions that might have contributed to the incident.

Instructor's Note

- Show Overhead #6, *Small Group Instructions*, and leave it on the screen while the groups are meeting.

There are complete instructions on the screen and on the first page of Handout #2. In your group, follow these steps:

1. Read and discuss your Case Study.
2. List possible latent conditions that might have contributed to this situation.
3. Choose someone to record your possible latent conditions on a flipchart sheet as you work. Also choose someone to present and explain your answers to the class later.
4. Divide your flipchart sheet into four categories: Operator Characteristics, Task Characteristics, Physical Environment and Workplace, and Organization and Management Factors. Try to identify some latent conditions in each category. Remember that the categories may overlap.
5. Next, on the Condensed Latent Conditions Checklist (Handout #1), mark the questions you think are most helpful.
6. As you use the Checklist, think about how useful it is (or isn't) in helping you understand the issues in the Case Study. We'll be discussing this question later in the class.

In coming up with your answers, try to get down to the most basic latent conditions. Emphasize issues involving design and management systems. For example, if a valve isn't labeled, the problem could be the overall labeling program, not the one missing label.

You'll have about 15 minutes.

Instructor's Note

- Divide the class into groups of 5 or 6 people each.
- Assign each group **one** of the three Case Studies you have chosen. (It's OK to give the same Case Study to more than one group.)
- Give each group a blank flipchart sheet and a set of markers. Ask them to choose someone to record their list of possible latent conditions on this sheet.
- Ask each group to choose someone to report and explain their answers to the whole class later.
- Also ask them to mark relevant questions on the Checklist (Handout #1) for their own reference, and to think about whether the Checklist is useful.
- Circulate among the groups as they work to make sure they are on track and to answer any questions.

4. Report back and discussion.

(20 minutes)

Instructor's Note

- After 15 minutes, bring the class back together.
- In turn, ask each group's designated person to report. They should:
 - Briefly describe the group's Case Study.
 - Show the group's flipchart sheet and explain the three or four most important latent conditions they identified.
 - Give the category in which they placed each one.
- Others in the group can add to the report if they wish. Allow time for the class to discuss the answers.
- As the groups report, compare their answers to the examples in the *Instructor's Discussion Guide* below.

Instructor's Discussion Guide

The questions below suggest some of the latent conditions that may exist in each Case Study. Remember that groups may come up with ideas which are not shown here, but which are equally valid.

Case Study One—Forgot To Turn a Valve

Operator Characteristics

- What training was provided to the operator?
- What was the operator's experience level?
- Why didn't the operator request help?
- Why did the operator get 30 days? Was it a repeat offense?

Task Characteristics

- Why were there no written procedures for this task?
- Was there a conflict between policy and practice?
- Was supervision inadequate? Did someone give approval?

Physical Environment and Workplace

- Why was the labeling poor?
- Were time, weather, or lighting a problem?
- Why didn't the system warn about the improper line-up?

Organization and Management Factors

- Why were there inadequate training and procedures?
- Why was there no follow-up on previous concerns?
- Were disciplinary procedures fair?

Case Study Two—Preparing for Unit Startup

Operator Characteristics

- What general and specific training was provided?
- Were stress and fatigue because of overtime a problem?
- Were late night hours a problem?

Task Characteristics

- Were there written procedures for this task?
- Did the operator have the right PPE for this task? Was the face shield adequate?

Physical Environment and Workplace

- Was the location of the bleeder valve unsafe?
- Was lighting a problem?
- Were there enough eye wash stations in convenient locations?

Organization and Management Factors

- Why did management schedule this job for the last minute?
- Why was the job scheduled at night when workers are less alert?
- Why did management require so much overtime?

Case Study Three—Too Many Alarms

Operator Characteristics

- Was the training program adequate?
- Were operators overworked or stressed?

Task Characteristics

- Were critical alarms overlooked because so many alarms were going off?
- Was the control system adequate for emergency situations?
- What were the written procedures for bypassing alarms? Were these procedures reasonable and workable?

Physical Environment and Workplace

- Were there any “nuisance” alarms or “phantom” alarms?
- Why did one problem trigger ten or more critical alarms? Should the alarm system be redesigned?

Organization and Management Factors

- Was staffing adequate? Had there been a study of workload?
- Did operators have real authority to shut down the unit without suffering consequences?
- Why did operators rarely have time to get permission to deactivate alarms?
- Were operators punished for bypassing alarms?
- Why did operators ignore written procedures?

Case Study Four—Storage Tank Failure

Operator Characteristics

- Did the welders have experience doing this task?
- Were the welders trained on proper procedures and on the dangers of combustibles?
- Was the person who monitored the atmosphere or calibrated the machine properly trained?

Task Characteristics

- Were welding and hot work procedures adequate?
- Did the welders check for ignition sources?
- Why were the manways not properly covered and sealed?
- Was the fire watch fulfilling his responsibility?
- Did anyone check for combustibles after the break, given that the day was getting warmer?
- Was there an alternative to welding the stairway, given the hazards?

Physical Environment and Workplace

- Was there proper spacing between the tanks?
- Were the tanks regularly inspected and tested for leaks and corrosion?

Organization and Management Factors

- Did management have a proper hot work permit system?
- Did management have a system in place to check for vapor and ignition sources?
- Did the safety officer have proper training and experience in preparing hot work, especially in identifying vapor and ignition sources?
- Did management have an adequate mechanical integrity program for the tank storage area?

Case Study Five—Catalyst Loading Emergency

Operator Characteristics

- Was the Unit Operator adequately trained in emergency response procedures?
- Were the maintenance workers and Unit Operator adequately trained in confined space procedures?
- Was the Unit Operator adequately trained in the use of SCBA, including the limits of the air supply?

Task Characteristics

- Was there an alternative way to load catalyst without entering the vessel?
- Was the catalyst loading job properly planned and supervised?

- Why wasn't leak monitoring performed prior to starting the job?
- Why was the ungrounded sock not discovered during a routine inspection?
- Why did the Unit Operator violate procedures in not calling for emergency help, not testing the atmosphere before entering the vessel, and going in without a hole watch?

Physical Environment and Workplace

- Why wasn't the sock grounded when installed?
- Why didn't the worker have a grounding strap?
- Why wasn't the worker attached to a safety line so he could be pulled out?
- Did the company consider the possible dangers of heavy, bulky PPE?
- Why didn't the PPE include a two-way communication device?

Organization and Management Factors

- Why did management reward the Unit Operator for violating procedures?
- Were the confined space program and confined space training adequate?
- Were the emergency response program and emergency response training adequate?

For more information on issues involved in these Case Studies, refer to the factsheets used in Lesson Two (Handouts #5-14).

Instructor's Note

- After all the groups have reported, continue by asking the entire class the questions below.
- Let volunteers answer. Hold a short class discussion of the answers people give.

ASK: "How useful was the Checklist in analyzing your Case Study? For example, did you find a lot of questions on the Checklist that applied? Did the Checklist validate what you already thought? Were any questions on the Checklist unclear?"

ASK: "How would you change the Checklist to make it more useful? For example, would you add more questions? What kind? Would you eliminate questions? Would you change the format?"

5. Using a Checklist.

(5 minutes)

Let's look at a few more issues involved in using the County's Latent Conditions Checklist (or any similar checklist).

Instructor's Note

- Show Overhead #7, *Who Will Use the Checklist?*

First, **who** will use a checklist? It may be used by anyone at the plant who is involved with process design or safety, including:

- Process Hazard Analysis (PHA) Teams
- Process Safety Management (PSM) Teams
- Incident Investigation Teams
- Management of Change (MOC) Teams
- Emergency Response Teams
- Engineers and process designers
- Health and Safety Committees
- Those who write or review operating procedures
- Frontline operations and maintenance workers.

Next, **what** checklist should be used? The County has developed a sample checklist. We used a condensed version of it (Handout #1) in the Case Studies. The County's checklist can serve as a resource for creating a custom version for each plant. Your own company may have developed a checklist that is specific to your facility. If you are interested, ask your plant human factors committee or safety committee about this.

The County suggests that any checklist you use be adapted to local conditions and tailored for each specific situation. It also recommends that operators be involved when this is done.

Finally, **how** should a checklist be used? Whichever checklist you use, remember that it is a tool. Tools only work well when used correctly.

We looked before at Page 2 of Handout #1, "Using the Checklist." It gives some tips about the County Checklist, and makes some good points about using it as part of a systematic effort to find and correct latent conditions.

Instructor's Note

- Show Overhead #8, *Using a Checklist*.

This overhead sums up the most important points about using a checklist to find latent conditions. We can divide these points into three categories: before, during, and after.

Before use of a checklist:

- Provide special training for checklist users so they understand the reasons for each question.
- Make sure the checklist will be used by people who understand the tasks and equipment involved.

During use of a checklist:

- Use the checklist to prompt further investigation. Add new questions if appropriate.
- Justify each answer and give supporting examples.

After use of a checklist:

- Checklist users and management should sign off that the checklist has been properly completed.
- Develop and implement recommendations to fix the problems identified.

The last point is probably the most important. When using a Checklist, the real purpose is to find ways to improve conditions.

6. Recommending solutions.

(5 minutes)

Whatever tool you use to look for latent conditions, the ultimate goal of the whole process is to find and implement solutions that will make the workplace safer and prevent future accidents. The key is to make sure that the problems identified are carefully analyzed and that solutions are developed that address the real underlying problems. Finally, there must be a systematic means of follow-up to make sure the solutions actually get put in place.

Instructor's Note

- Show Overhead #9, *Recommending and Implementing Solutions.*

Here's a summary of the human factors approach to solutions. After using a checklist, develop recommendations following these guidelines:

- Focus on underlying policies, procedures, and practices. The latent conditions identified on a checklist are often symptoms of bigger problems. A missing label can mean that the whole system of labeling should be reviewed and improved.
- Aim to fix programs or systems that allowed unsafe conditions to exist. Don't simply correct particular problems.
- Determine which major programs are most in need of improvement. Set priorities.

- Involve operators and maintenance staff in developing recommendations.
- Look for multiple recommendations. Just as a problem can have many causes, it may also have many possible solutions.
- Have a tracking system to make sure recommendations get implemented.
- Inform all employees of steps that have been taken to fix the problems.

As you can see, checklists are just one part of the process of identifying hazards and making changes.

What's needed is an overall human factors program. In Lesson Four, we'll go into more detail on the elements of a good program.

This concludes Lesson Three. Handout #3 in your binder has more information on how human factors makes recommendations.

Lesson Three Overheads



In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Lesson Three Overhead #1

The Human Factors Method

WHAT

Study **accidents**
to find causes

Study the **workplace**
to find hazardous
conditions



WHY

- To remove hazards
- To improve safety
- To prevent future accidents



HOW

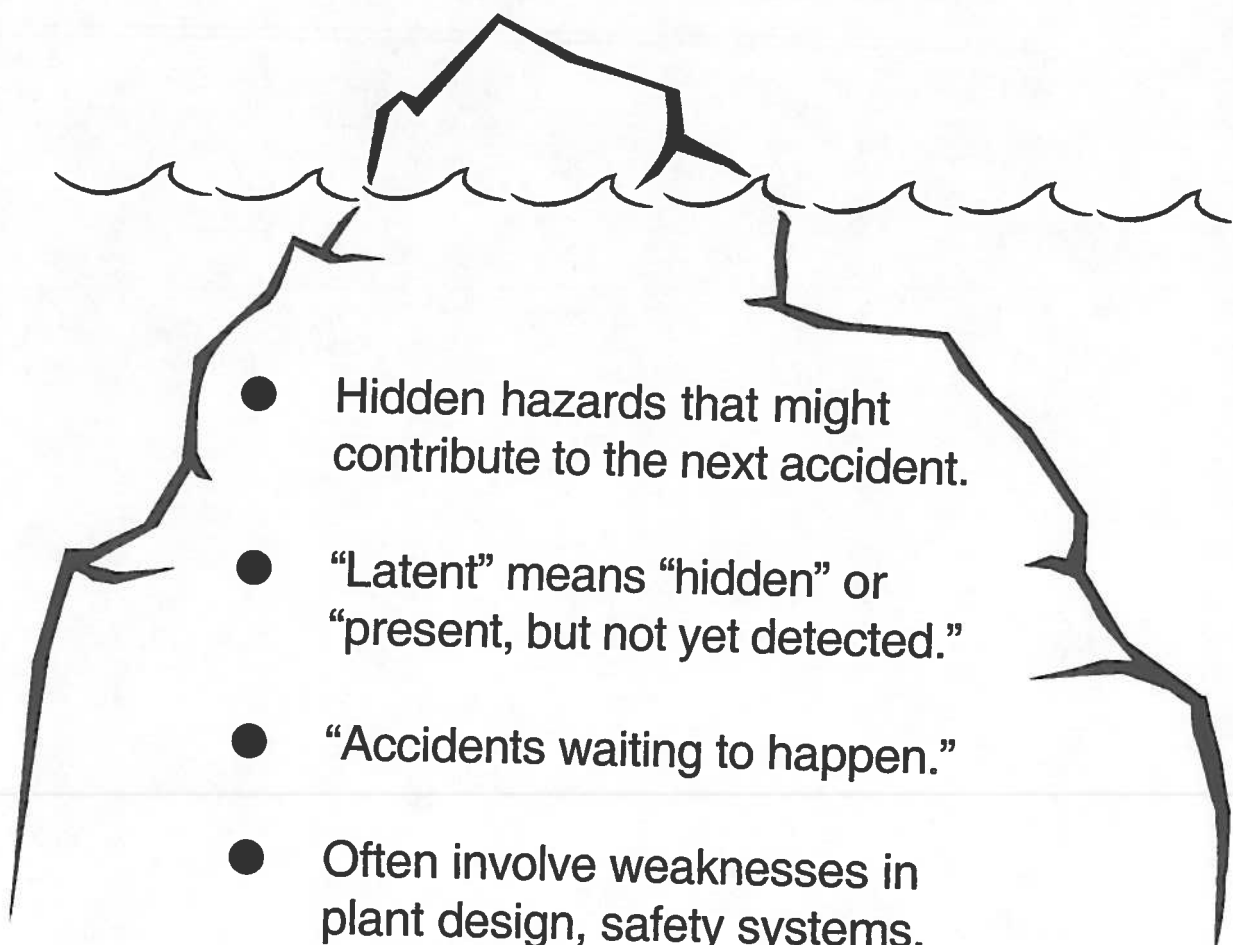
Match equipment and
work processes to
human limits,
capabilities, and needs



In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Latent Conditions



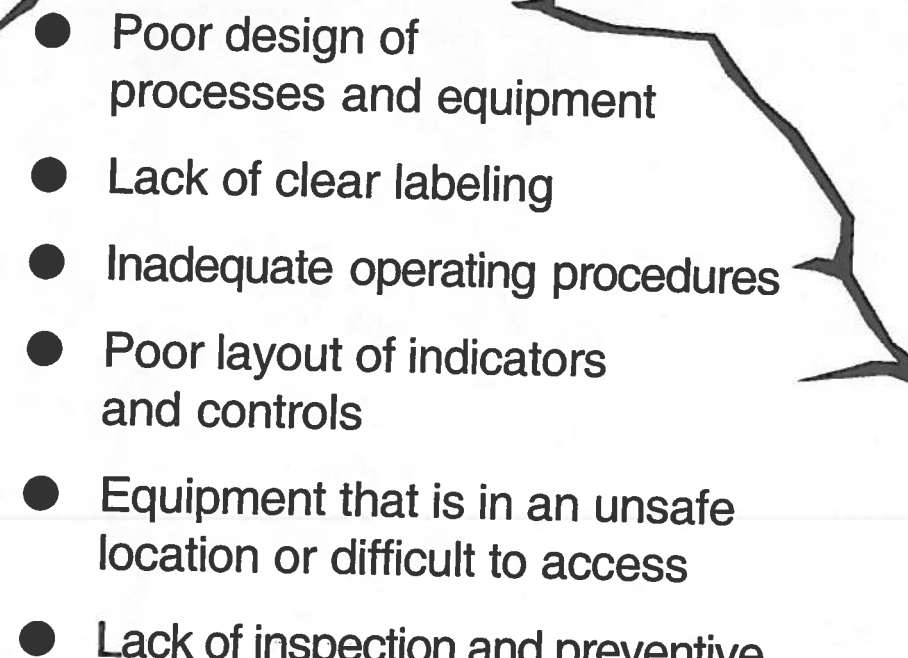
- Hidden hazards that might contribute to the next accident.
- “Latent” means “hidden” or “present, but not yet detected.”
- “Accidents waiting to happen.”
- Often involve weaknesses in plant design, safety systems, or management.
- Directly related to human error, because they make it harder for people to do their jobs well and they make mistakes more likely.



In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Examples of Latent Conditions

- 
- Poor design of processes and equipment
 - Lack of clear labeling
 - Inadequate operating procedures
 - Poor layout of indicators and controls
 - Equipment that is in an unsafe location or difficult to access
 - Lack of inspection and preventive maintenance
 - Inadequate training for normal and emergency situations
 - Fatigue due to long hours or late hours
 - Inadequate staffing levels.

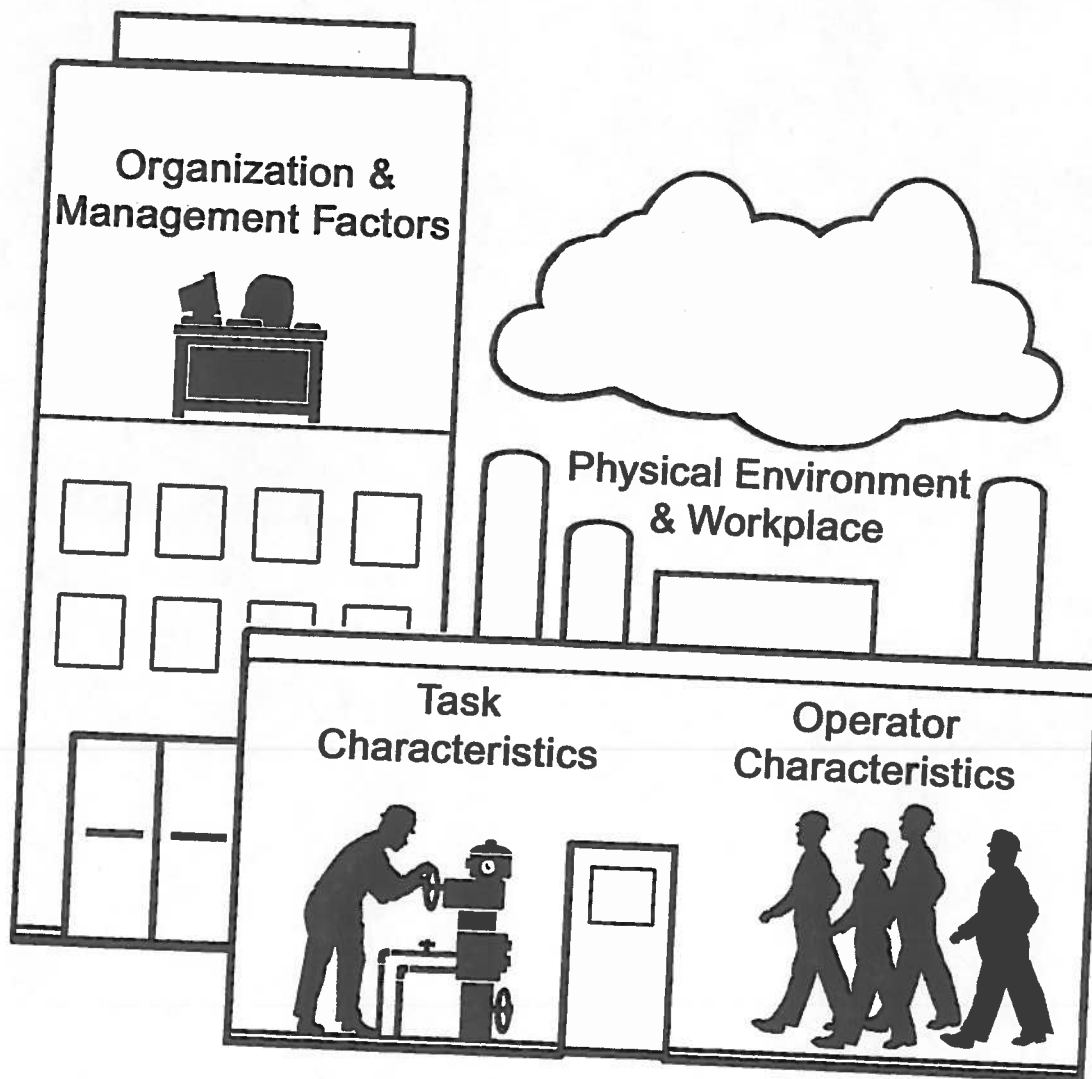


In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Lesson Three Overhead #4

Four Point Approach to Safety





In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Lesson Three Overhead #5

Categories of Latent Conditions

- ✓ **Operator Characteristics**

- ✓ **Task Characteristics**

- ✓ **Physical Environment and Workplace**

- ✓ **Organization and Management Factors**



In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Small Group Instructions

1. Read and discuss your Case Study.
2. List possible latent conditions that might have contributed to this situation.
3. Choose someone to record your possible latent conditions on a flipchart sheet as you work. Also choose someone to present and explain your answers to the class later.
4. Divide your flipchart sheet into four categories: Operator Characteristics, Task Characteristics, Physical Environment and Workplace, and Organization and Management Factors. Try to identify some latent conditions in each category.
5. Next, on the Condensed Latent Conditions Checklist (Handout #1), mark the questions you think are most helpful.
6. As you use the Checklist, think about how useful it is (or isn't) in helping you understand the issues in the Case Study.



In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Lesson Three Overhead #7

Who Will Use the Checklist?

- PHA or PSM Teams
- Incident Investigation Teams
- Management of Change (MOC) Teams
- Emergency Response Teams
- Engineers and process designers
- Health and Safety Committees
- Those who write or review operating procedures
- Frontline operations and maintenance workers.



In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Using a Checklist

Before:

- Provide special training for checklist users.
- Make sure the checklist will be used by people who understand the tasks and equipment involved.

During:

- Use the checklist to prompt further investigation. Add new questions if appropriate.
- Justify each answer and give supporting examples.

After:

- Users and management should sign off that the checklist has been properly completed.
- Develop and implement recommendations to resolve the problems identified.



In Your Own Words

If you wish, use this space for your own notes. Before class, list important points from the Lesson Plan for easy reference while teaching.

Recommending and Implementing Solutions

- Focus on underlying policies, procedures, and practices.
- Aim to fix programs or systems that allowed unsafe conditions to exist. Don't simply correct particular problems.
- Determine which major programs are most in need of improvement. Set priorities.
- Involve operators and maintenance staff in developing recommendations.
- Look for multiple recommendations. Just as a problem can have many causes, it may also have many possible solutions.
- Have a tracking system to make sure recommendations get implemented.
- Inform all employees of steps that have been taken to fix the problems.

Lesson Three Handouts



Condensed Latent Conditions Checklist

Table of Contents

	Questions
Operator Characteristics	
Experience and Knowledge	1-2
Stress and Fatigue	3-4
Shiftwork	5-8
Task Characteristics	
Procedures	9-17
Practices	18
Conflicts Between Practice and Procedure	19
Physical Environment and Workplace	
Process Design and Labeling	20-21
Control Room/Panel Design	22-25
Safeguards	26-27
Work Environment	28-30
Organization and Management Factors	
Communications	31
Training	32-34
Staffing and Overtime	35-37
Climate and Culture	38-40
Management System	41-47

Using the Checklist

On the county's Latent Conditions Checklist, enter **Y** (yes), **N** (no), or **NA** (not applicable) for each item. See the explanation at the bottom of page 3 (opposite).

The small numerals that appear after most items refer to sources of further information. See the "References" section at the end of this handout.

Checklists are easy to use but can be ineffective without formal programs and procedures to fix the problems they identify. When using the checklist, keep these points in mind:

- "No" answers are often symptoms of "bigger picture" problems. Don't just fix the immediate problem—also fix the program that allowed the problem to exist.
- Checklist users must be trained to understand the specific reason for each question, the relative importance of different questions, and the degree to which items fail to meet the criteria. Users must also understand the tasks being carried out at the plant.
- Operators should be informed that the intent isn't to identify their errors but rather to identify and rectify latent conditions that could cause them to make an error.
- Use the checklist to prompt further investigation. Add new questions if appropriate.
- Think about each question—don't simply "check boxes." Try to justify each answer and give supporting examples. Remember that your checklist may be reviewed years later by personnel not involved today.
- Checklist users and management should sign off that the checklist has been appropriately completed.
- Thoroughly analyze any questions with a "No" answer. Recommendations should be developed and implemented to resolve these problems. Operations and maintenance staff as well as management should be involved in this process.
- There should be a formal "feedback" loop to inform all personnel of the recommendations and to ensure that these will adequately address the concerns.
- There should be a formal tracking mechanism to ensure that recommendations are implemented in a timely fashion.

—Excerpted from *Contra Costa County Safety Program Guidance Document, 12/99*

Condensed Checklist

This is a short version of the Contra Costa County Latent Conditions Checklist. For the complete Checklist, contact your plant's human factors committee, safety committee, or Contra Costa Department of Health Services, Hazardous Materials Programs.

Checklist Questions	Y/N/NA	Justification/Examples
<p>1. OPERATOR CHARACTERISTICS</p> <p>Experience and Knowledge</p> <ol style="list-style-type: none"> 1. Do employees remain in each unit for a sufficient amount of time to develop the experience and knowledge base necessary to safely operate the unit and respond to emergencies?¹ 2. Do operators have sufficient knowledge to safely operate or shutdown the unit in emergency situations where they must assume manual control?¹ <p>Stress and Fatigue</p> <ol style="list-style-type: none"> 3. Are emergency procedures presented in a clear, step-by-step format to reduce the "panic" factor during upset situations?² 		

- Y = Concern raised by the question has already been addressed. No further documentation is required.
- N = Concern raised by the question has not already been addressed. Further analysis and documentation are required. The PHA team should fully develop the concern using an approved PHA methodology.
- NA = Concern raised by the question is not applicable for the area under consideration.

Lesson Three Handout #1
Page 4

Checklist Questions	Y/N/NA	Justification/Examples
<p>4. Are there jobs that are beyond employees' physical limits or safe physical limits (e.g., carrying equipment, that requires both hands, up stairs that are poorly lighted at night)?^{1 & 8}</p>		
<p>Shiftwork</p>		
<p>5. Is the length of a normal shift appropriate given the degree of alertness required and potential for operator fatigue [<i>consider number of manual adjustments required in a single shift, effect of rotating shifts</i>]?²</p>		
<p>6. Is the length of a shift during startup and turnaround appropriate given the degree of alertness required and potential for operator fatigue?²</p>		
<p>7. Are shift turnover periods sufficient to adequately communicate plant operating conditions from off-shift to on-shift personnel?²</p>		
<p>8. Are job turnover communications within shifts adequate?¹</p>		
<p>2. TASK CHARACTERISTICS</p>		
<p>Procedures</p>		
<p>9. Do written procedures exist for unique or critical operating or maintenance tasks such as catalyst regeneration, catalyst sulfiding, etc.^{6 & 8}</p>		
<p>10. Are procedures certified as being current and accurate?¹</p>		

Lesson Three Handout #1
Page 5

Checklist Questions	Y/N/NA	Justification/Examples
11. Do the procedures require "sign-offs" for critical steps or when completion of the procedure may require coordination with others (e.g., numerous shifts or operators)? ⁵		
12. Do the procedures contain enough detail to adequately enable a trained operator to perform all modes of operation? ⁶		
13. Do procedures prevent changing alarm set points without proper review and authorization? ²		
14. Do the procedures specify the potential consequences if the alarm set points are exceeded (i.e., consequences of deviation)? ²		
15. Are operating crews provided with written temporary operating procedures when equipment, controls, or instruments are bypassed or out of service? ^{2 & 3}		
16. Can emergency procedures be implemented whether or not the operator knows what is wrong (i.e., are they "symptom" based rather than "event" based)? ⁴		
17. Do procedures require that individuals perform multiple tasks simultaneously that practically cannot be performed? ¹		
Practices		
18. Does the facility attempt to minimize hazardous or high risk work during night shifts (i.e., does facility management recognize that individuals have a tendency to be less alert during night/early morning hours and take special precautions)? ¹		

Checklist Questions	Y/N/NA	Justification/Examples
<p>Conflicts Between Practice and Procedures</p> <p>19. Are the procedures consistent with actual operating practices, particularly operating practices responding to emergency or upset conditions?¹</p>		
<p>3. PHYSICAL ENVIRONMENT & WORKPLACE</p>		
<p>Process Design and Labeling</p>		
<p>20. Are shutdown switches and other controls required for emergency operation readily accessible to the operator from a safe location?³</p>		
<p>21. Are all equipment labels correct and unambiguous?²</p>		
<p>Control Room/Panel Design</p>		
<p>22. Does the process control system console layout allow for rapid response to upset situations?²</p>		
<p>23. Are alarms arranged, or otherwise coded, according to their level of urgency (i.e., is there an alarm priority system)?⁴</p>		
<p>24. Is the cause of "nuisance" alarms (repetitive alarms that operations personnel ignore or acknowledge without investigating) determined and repaired in a timely manner?²</p>		
<p>25. Does the level of automation allow sufficient operator involvement so operators do not feel detached from the process, particularly during emergency situations where they must assume manual control?¹</p>		

Lesson Three Handout #1
Page 7

Checklist Questions	Y/N/NA	Justification/Examples
Safeguards		
26. Are escape routes clearly labeled, lighted, and maintained clear of obstacles? ²		
27. Does the protective gear allow freedom of movement necessary to perform necessary tasks (routine and emergency)? ⁸		
Work Environment		
28. Is the lighting adequate in the unit [<i>consider local instrument panels, battery or plot limit valve manifold locations, equipment and valves requiring operation during emergency conditions, etc.</i>]? ²		
29. Are the control building air conditioning and pressurization adequate to prevent intrusion of toxics, flammables, or corrosive contaminants (if applicable)? ²		
30. Are employees protected from excessive noise? ¹ NOTE: "Excessive" to the point that it affects mental workload and cognitive ability as opposed to physical harm (e.g., "It is so loud I cannot concentrate.")		
4. ORGANIZATION & MANAGEMENT FACTORS		
Communications		
31. Is there an environment of trust between on-line workers and supervision, such that feedback communications are used? ¹		

Lesson Three Handout #1
Page 8

Checklist Questions	Y/N/NA	Justification/Examples
Training		
32. Does the operator training program cover all of the operating procedures and required operations, including emergency operations? ⁶		
33. Are risks, penalties, and performance goals for both process and operator behavior emphasized during training? ⁴		
34. Are operators trained in diagnostic skills which will help them cope in unfamiliar situations? ⁴		
Staffing and Overtime		
35. Are staff levels (both size and experience) sufficient to handle routine and nonroutine duties that can be reasonably expected to occur during a shift? ²		
36. Is there backup assistance when an operator emergency responder must respond to an emergency? ³		
37. Are restrictions applied to employee overtime (e.g., employees are not allowed to work consecutive 12-hr. shifts)? ¹		
Climate and Culture		
38. Is a management philosophy that safety takes precedence over production adequately covered? ¹		
39. Have supervisors and workers been specifically told to err on the safe side whenever they perceive a conflict between safety and production? ²		

Lesson Three Handout #1
Page 9

Checklist Questions	Y/N/NA	Justification/Examples
40. Do workers feel that unsafe operations or maintenance activities can be shutdown without fear of retaliation? ^{1 & 7}		
Management System		
41. Does senior management prohibit contract terms and conditions that are not consistent with safe working conditions (e.g., accelerated schedules, reduced quality requirements)? ⁷		
42. Does lower management ensure that required procedures are developed and kept current to assure a safe work environment? ⁷		
43. Does lower management have a system for identifying and disseminating work process lessons learned? ⁷		
44. Do first line supervisors discuss job hazards with workers prior to starting work? ⁷		
45. Do first line supervisors confirm the readiness to perform work prior to the execution of work? ⁷		
46. Does senior staff ensure that there is expertise available in each of the different Safety Program elements, including Human Factors? ¹		
47. Does senior staff allocate time and resources for the different Safety Program elements? ¹		

References

- 1 Contra Costa Health Services
- 2 EQE International, PHA Checklist: Human Factors, developed for and used by Chevron and Tosco (1996)
- 3 MRC Human Factors Review Checklist (1994)
- 4 Primatech Human Factors Checklist (1994)
- 5 Guide to Reducing Human Error In Process Operation, Short Version (1985)
- 6 Center for Chemical Process Safety, Guidelines for Writing Effective Operating and Maintenance Procedures (1996)
- 7 U.S. Department of Energy, Workbook for Conducting Accident Investigations, Revision 1, November 21, 1999
- 8 RRS Engineering Human Factors Checklist (1999)
- 9 AcuTech (1999)
- 10 Chemical Manufacturers Association, A Manager's Guide to Reducing Human Errors (1990)

—Checklist from Contra Costa County Safety Program Guidance Document, 12/99

Refinery Case Studies

Instructions

Your small group will be assigned to work on **one** of the Case Studies in this handout. All of them describe actual incidents that occurred in refineries.

You'll have about 15 minutes. In your group, follow these steps:

1. Read and discuss your Case Study.
2. List possible latent conditions that might have contributed to this situation.
3. Choose someone to record your possible latent conditions on a flipchart sheet as you work. Also choose someone to present and explain your answers to the class later.
4. Divide your flipchart sheet into four categories: Operator Characteristics, Task Characteristics, Physical Environment and Workplace, and Organization and Management Factors. Try to identify some latent conditions in each category. Remember that the categories may overlap.
5. Next, on the Condensed Latent Conditions Checklist (Handout #1), mark the questions you think are most helpful.
6. As you use the Checklist, think about how useful it is (or isn't) in helping you understand the issues in the Case Study. We'll be discussing this question later in the class.

Case Study
One

Forgot To Turn a Valve

A supervisor called and asked to have the caustic lined-up to the Alky plant. The #2 operator took the call. He went out and looked over the job. There were no written procedures available. The labeling was poorly done and fading.

The #2 operator reasoned it out as best he could. After double checking the flow, he decided he had it right and set the flow to the Alky.

Later he heard on the radio that the Alky unit was in trouble and might have to shut down. He quickly set the line-up back, and then called to inform the foreman that he might know what had happened.

An investigation revealed that the #2 operator had missed turning a valve. This caused the caustic to go the wrong way and knocked the Alky plant off-line. The mistake cost the company over \$100,000.

Other operators had also complained the lack of procedures, and about poorly marked lines and valves. The #2 operator received a 30-day suspension.

Case Study
Two

Preparing for Unit Startup

After a 30-day shutdown for repairs, a refinery unit was being started back up. During the shutdown, several operators had worked 12-hour shifts for 21 days without a day off.

One of these operators was assigned to take a complicated acid piping manifold out of service during the graveyard shift so a new line could be tied in the next morning. The new tie-in had been planned for many months, but had not been scheduled before because it was not an urgent job.

The operator missed closing one of the 12 isolation valves on the piping manifold. A few seconds after he opened a small bleeder valve, a plug of solid material cut loose from the valve. Acid sprayed out, hit the pavement, and bounced up under the operator's face shield.

With acid in his eyes, the operator could not find the emergency shower and eye wash station. Luckily, another worker walked by and got him to the eye wash.

Case Study
Three

Too Many Alarms

Corporate Headquarters asked all refineries to run an analysis of their alarm systems. Refinery X printed out a log showing when and where different types of alarms had been activated. They presented the data to a human factors working group, which included both labor and management members.

Looking at just one 24-hour period, the working group noted that over 6,000 alarms were triggered. Dozens of them were "critical limit" alarms on various process units.

The hourly workers at the meeting mentioned that this had been a source of frustration and stress for the board operators. They explained that it's impossible to handle 75 alarms going off at the same time. Sometimes up to ten critical alarms are triggered during one upset, as the system bounces back and forth between the high and low set limits. Everything happens so fast that there simply isn't time for the operator to figure things out.

Sometimes operators think that if they bypass and deactivate the alarms, they have a better chance to get the unit back under control. However, there rarely is time to get the required permission from the department manager. When alarms become overwhelming, the procedures say the operator should shut the unit down. But because this happens so often, operators are reluctant to do so.

The hourly workers in the working group think that the new information from the log supports their concerns. Another working group member points out that this is evidence of a latent condition: it's not linked to a particular incident but is a potential hazard that needs to be investigated further.

Case Study
Four

Storage Tank Failure

Note: About 25% of the top 100 accidents in the petrochemical industry have occurred in chemical storage areas.

Two refinery maintenance workers were assigned to weld a handrail to a set of stairs shared by two large storage tanks. The tanks contained waste mixtures of water, oil, and other hydrocarbons. They had been built in 1937, and were constructed of steel plates riveted together.

The tanks were not individually diked, but were in an area with walls and berms to prevent any spilled material from reaching the local creek.

The company safety officer issued a "hot work" permit, valid from 7:30 a.m. to 3:30 p.m. He inspected the setup before giving final approval for the welding. The permit required stationing a fire watch, covering all manways at the top of the tanks, grounding the welding machines, and conducting combustible gas monitoring prior to welding.

One manway hole was used to run a hose from the vacuum trucks to the tank. This hose prevented the manway cover from completely sealing the opening, but a welding blanket was draped over the manway.

The area was prepared and work began around 7:45 a.m. The welders took a break around 9:30 a.m. By then, the sun had come out and the day was getting warmer. They resumed work around 10:00 a.m. Minutes later, an explosion occurred in the first tank. The tank failed at its bottom seam and shot up in the air, releasing its entire contents. The second tank exploded and the fire spread, engulfing nearby contractor trailers and other areas. One welder and two contract workers who were in the trailers were killed immediately. The other welder, who had been serving as fire watch, and another contract worker died days later.

The incident investigation found that the immediate cause of the fire and explosion was the ignition of flammable vapors in the first tank. At least four possible vapor sources were identified. The most likely ignition source was the welding operation.

Case Study
Five

Catalyst Loading Emergency

A unit was down for turnaround. New catalyst was being loaded into a reactor. The catalyst was loaded through a "sock," which was not grounded.

A maintenance worker was inside the reactor, spreading the catalyst as it came down the chute. He was wearing protective equipment, including a large cumbersome "clamshell" to protect him from breathing the catalyst dust. He was supplied with fresh air through a hose.

Other maintenance workers were just outside the reactor, assisting with the loading. One of them was serving as "hole watch" for the inside worker's fresh air supply.

During the catalyst loading, static electricity ignited vapors that were leaking from a source nearby. The resultant explosion knocked the maintenance worker onto his back and broke the light inside the reactor. The worker was uninjured. However, he was now in complete darkness, could not hear anything, and could not get up off his back because of his bulky protective equipment. The maintenance workers outside received flash burns and were incapacitated.

The Unit Operator rushed to the area, put on a Self-Contained Breathing Apparatus (SCBA), and went into the reactor to rescue the maintenance worker. He did not call for emergency responders before he went into the reactor, nor did he check the atmosphere. Company policy states that in this type of situation, an emergency should be declared and only emergency response personnel should rescue anyone trapped in a confined space.

The Unit Operator found the maintenance worker and helped him to the ladder. Just then the Unit Operator's air supply was exhausted. Fortunately, the confined space atmosphere was no longer hazardous when this occurred.

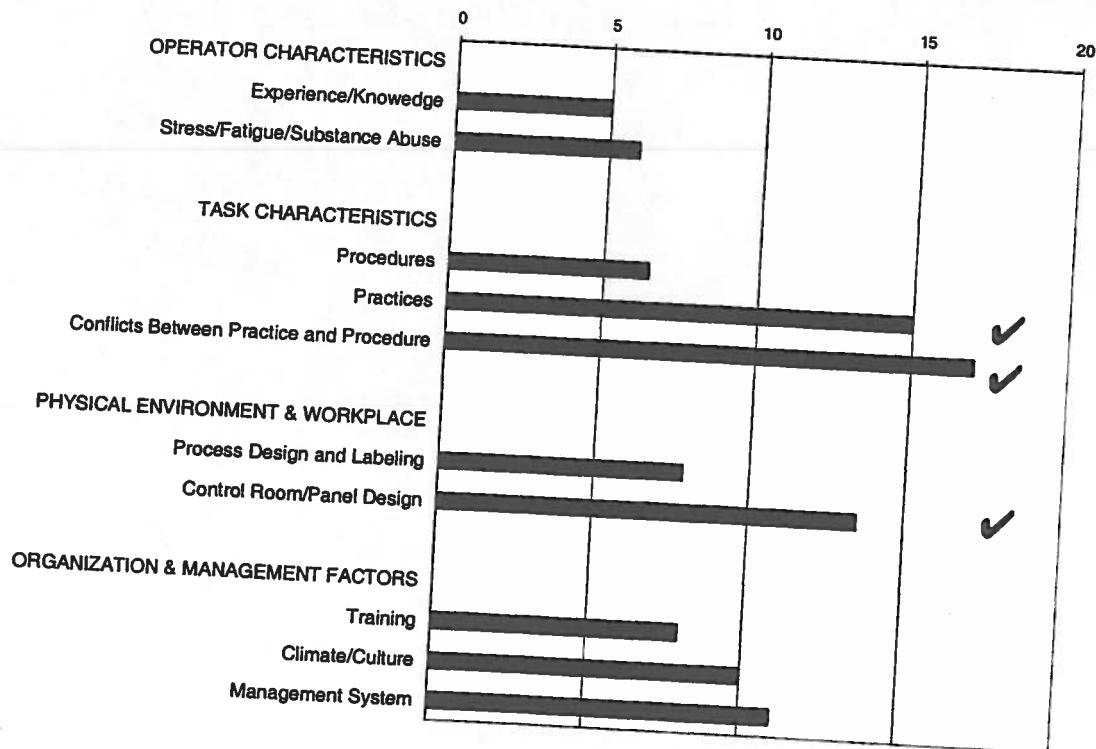
The Unit Operator was celebrated as a hero for rescuing the maintenance worker.

Human Factors Recommendations

The ultimate goal of a human factors investigation is to make recommendations for change. When using a human factors approach to solve problems, keep these points in mind:

- **Focus on underlying policies, procedures, and practices.** Human factors recognizes that the latent conditions identified on a checklist are often symptoms of bigger problems. A missing label can mean that the whole system of labeling should be reviewed and improved. Human factors also examines the overall “safety culture” at the plant and how it is incorporated into specific policies, such as staffing levels, work schedules, automation, and control room design.
- **Determine which major programs are most in need of improvement.** Results from a latent conditions checklist can be analyzed to identify the weaker programs. This analysis can help a facility set priorities for making needed changes. In the example below, some categories stand out as most in need of correction.

NUMBER OF “NO” ANSWERS ON CHECKLIST



(continued)

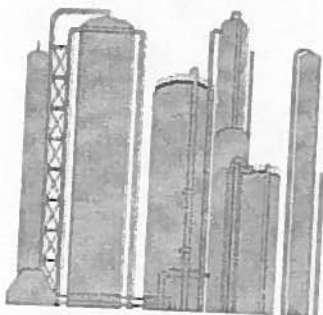
Lesson Three Handout #3

Page 2

Notice that the scores are derived by taking the number of "No" answers in each category from the Checklist. You can see that the categories with check marks (✓), which have the most "No" answers, are most in need of correction.

- **Look for multiple recommendations.** Just as a problem can have many causes, it may also have many possible solutions. The more defenses that are in place, the less chance of a random error resulting in a major accident. Many problems have solutions in several of the county's four categories.

**REFINERY TRAINING
PROGRAM**



LESSON

4

Your Company's Safety Plan

A Note on This Lesson

Each facility should develop its own Lesson Plan for Lesson Four. This may include a presentation by the company, explaining the specifics of its new safety plan and the role that human factors methods will play. To be consistent with the teaching style of the previous lessons, there should be opportunities for questions and class discussion. If possible, prepare a few visual aids (Overheads) about the company safety plan. You may also want to distribute the written safety plan and/or related materials as Handouts. Tabbed sections are provided in this binder to add your Lesson Plan and any Overheads and Handouts.

